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ENTOMOLOGICAL SOCIETY OF ONTARIO

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Volume One Hundred

1969

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Published September, 1970
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THE HONOURABLE WILLIAM A. STEWART
Minister of Agriculture and Food for Ontario

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of the
ENTOMOLOGICAL SOCIETY OF ONTARIO

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THE HONOURABLE WILLIAM A. STEWART
Minister of Agriculture and Food for Ontario

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1. REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

INSECTS OF THE SEASON 1969 RELATED TO FRUIT, VEGETABLES, FIELD CROPS AND ORNAMENTALS

H. W. Goble

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Abstract

A resume of the occurrence in Ontario in 1969 of several species of insects affecting fruit, vegetables, field crops and ornamental plants.

Fruit

The damage caused by most fruit-infesting insects was light. This included the codling-moth, *Carpocapsa pomonella* (Linnaeus), apple maggot, *Rhagoletis pomonella* (Walsh), cherry fruit flies, *Rhagoletis* spp., red-banded leaf roller, *Argyrotaenia velutinana* (Walker), and Oriental fruit moth, *Grapholitha molesta* (Busck). The plum curculio, *Conotrachelus nenuphar* (Herbst), was more troublesome on apples and plums than for a number of years. Aphid infestations were generally light except for moderate infestations on plums in August. Infestations of oystershell scale, *Lepidosaphes ulmi* Linnaeus, on apple decreased in numbers. European red mites, *Panonychus ulmi* (Koch), were low in numbers until the hot, dry weather in September. Some species of eriophyid mites increased in numbers.

Vegetables

The cabbage looper, onion maggot, cutworms, and sap beetles were important in 1969. The cabbage looper, *Trichoplusia ni* Hübner continued to be very numerous and destructive although not quite as severe as in 1968. The onion maggot, *Hylemya antiqua* (Meigen), caused damage where adequate control measures were not applied. Infestations were considerably above normal. Several species of cutworms caused some crop loss. The black cutworm, *Agrotis ipsilon* (Hufnagel), caused severe damage to turnips in one area of Huron County in August. The infestation was not general throughout Ontario. There appear to be no earlier records of this pest on turnips. The garden slug is reported under Field Crops. The cabbage maggot, *Hylemya brassicae* Bouche, caused damage where adequate control was not applied. Most of the injury was in May and June and again in the fall. No pepper maggots, *Zonosemata electa* (Say), were found in peppers, but they were present in the wild host, horse nettle.

Field Crops

The garden slug, *Deroceras reticulatum* (Mull), continued to be a problem in some areas, especially on field corn. The injury to corn was in May and June

when the plants were becoming established. Slugs also damaged some vegetables and were important in home gardens. Plant bugs, leafhoppers, aphids, flea beetles, and other common insects were present but not in unusual numbers.

The alfalfa weevil, *Hypera postica* (Gyllenhal), was found throughout southern Ontario. The damage to first cut alfalfa was 50% in Essex County, decreasing along Lake Erie to 35% in Welland County. There was 30% damage in Prince Edward County and along Lake Ontario to Kingston. Damage was light in other areas. The cereal leaf beetle, *Oulema melanopus* (Linnaeus), was found from Essex, Kent and Lambton Counties east to York County. The spread was not dramatic like that of the alfalfa weevil. There was no important crop damage.

Ornamental Plants

The usual large numbers of complaints concerning insect damage to flowers, ornamental trees and shrubs were received. No insect, however, was reported to be in outbreak form. The bronze birch borer, *Agrilus anxius* (Gory), continued to be a problem, being particularly destructive to the cut-leaf weeping birch. The birch leaf miner, *Fenusa pusilla* (Lepeletier), was plentiful. The plant bug, *Orthotylus chlorionis* (Say), that, along with some leafhoppers, defoliated a few moraine locusts in 1968, was not serious in 1969. There was an unusual occurrence of *Yponomeuta multipunctella* Clemens on *Euonymus europea* and *E. nana* with the caterpillars completely defoliating these two species of spindle bush by June 10. Other species of *Euonymus* in the Guelph area were not attacked.

PLANT PARASITIC NEMATODES OF ECONOMIC IMPORTANCE IN ONTARIO

T. H. A. Olthof, J. L. Townshend, J. W. Potter, and C. F. Marks
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Abstract

A resume of the occurrence in Ontario in 1969 of several species of nematodes affecting plants.

Plant parasitic nematodes have an economic impact on crop production in Ontario. The most destructive ones are the root-lesion nematode, *Pratylenchus* Filipjev; the root-knot nematode, *Meloidogyne* Goeldi; the cyst nematode, *Heterodera* Schmidt; the dagger nematode, *Xiphinema* Cobb; the bulb and stem nematode, *Ditylenchus dipsaci* (Kühn) Filipjev, and the pin nematode, *Paratylenchus* Micoletzky.

In 1969, 16 vegetable crops were surveyed for nematode damage, and a total of 43 soil samples analyzed. Large numbers of root-lesion nematodes were found associated with stunted plants in fields of snap beans, cabbage, cauliflower, sweet corn, and onion. As males were present in most collections, *Pratylenchus penetrans* (Cobb) is believed to be the dominant species, rather than *P. neglectus* (Rensch.) Filip & Stek., also present in the areas investigated (Olthof *et al,* 1968). Severely stunted strawberry plants from Simcoe, Ontario contained as many as 7,000 root-lesion nematodes per pound of soil versus 5 per pound in healthy plants.

The northern root-knot nematode, *Meloidogyne hapla* Chitwood, was found in muck vegetable crops at Port Colborne, Ontario. Cabbage, lettuce, celery, carrots, and onions were affected. The nematode caused early formation of small bulbs which failed to develop further because of a reduction in top and root growth. The loss on onions represented about 10% of the crop. Root-lesion nematodes were also present in appreciable numbers, which possibly also affected the crops.

Several ectoparasitic nematodes were found associated with stunting and chlorosis of rhododendrons and azaleas grown in a greenhouse. The predominant nematodes were *Tylenchorhynchus claytoni* Steiner on rhododendron and the ring nematode, *Criconemoides* (Taylor), on azalea. Spiral nematodes, *Rotylenchus robusta* (de Man) Filipjev, stubby-root nematodes, *Trichodorus* Cobb, and another stunt nematode, *Tylenchorhynchus parvus* Allen, were also found about the roots of both these ornamentals. Nemagon 130 EC, at 5.5 oz in 50 gal of water applied to 1,000 sq ft drenched with an additional 50 to 100 gal of water was recommended for the treatment of established liner beds.

In 1969, the oat cyst nematode, *Heterodera avena* Wollenweber, persisted as a problem in areas where it has been previously reported (Olthof *et al,* 1968). Several growers south of Lake Simcoe who planted corn following two consecutive years of oats reported stunting and leaf symptoms resembling phosphorus deficiency in spite of favorable soil fertility tests. High oat cyst nematode populations were found in samples from these farms. Oats should not be planted two years in succession where this nematode is present. Similarly, corn should not follow oats directly; at least two seasons of forage or other non-cereal crop should intervene between an oat crop and a subsequent corn crop.

Preplant fumigation with nematocides against the root-lesion nematode is rapidly becoming established as a standard operation in the production of flue-cured tobacco in southern Ontario. In the spring of 1969, approximately 60,000 acres of tobacco land were treated with nematocides. This is an increase of about 100% over the acreage treated in 1968, and represents about 50% of the total area planted to tobacco in southern Ontario. Fumigation of 60,000 acres at an average cost of $30 per acre represents an investment of $1.8 million. As the average increase in yield due to fumigation is 200 pounds of tobacco (Olthof, 1967), worth approximately $130, the nematode control program in flue-cured tobacco is estimated to have increased the returns to growers by $6 million in 1969. Fumigation is recommended as a standard cultural practice for flue-cured tobacco production.

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INSECTS AND OTHER ARTHROPODS OF IMPORTANCE DURING 1969 IN HOUSEHOLDS AND ON LIVESTOCK IN ONTARIO

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Abstract

A resume of the occurrence in Ontario in 1969 of several species of insects and other arthropods invading houses and occurring on livestock.

Household

During 1969 fleas, Ctenocephalides spp., were the most common insect pests of households. Reports of heavy infestations were received from many parts of Ontario. Cluster flies, *Pollenia rudis* (Fabricius), did not reach the peak of former years and only a few instances of these flies causing concern in homes and buildings were recorded. European earwigs, *Forficula auricularia* (Linnaeus), again showed an increase over previous years and have now become a fairly common pest in both homes and gardens in most of southern Ontario. In the fall of 1969 springtails, (Collembola), appeared in large numbers in many areas but their presence was noted for a very short period and they did not build up to any great numbers. Millipedes, *Narcus* spp., sowbugs,, *Oniscus* spp., and centipedes, *Scutigera* spp., were occasionally found in cellars and damp basements.

In kitchens and pantries saw-toothed grain beetles, *Oryzaephilus surinamensis* (Linnaeus), were fairly common although not as many infestation reports were recorded in the past year.

Livestock

In general, face flies, *Musca autumnalis* (DeGeer), appeared to be more widespread and populations were active on cattle over a longer period of time than during the previous year. This fly is increasing as a major pest of horses during the summer months, particularly in urban areas where riding mounts are concentrated. Horn flies, *Haematobia irritans* (Linnaeus), were not a major pest during 1969 and no large populations on either beef or dairy cattle were recorded. Warble flies, *Hypoderma* spp., continued to be a problem in beef cattle in Ontario.

NOTEWORTHY FOREST INSECTS IN ONTARIO IN 1969

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Abstract

This review brings to the attention of entomologists insects that for a variety of reasons were of special interest to the Forest Insect and Disease Survey in Ontario in 1969. It describes the current situation respecting major forest pests and new or unusual entomological problems on coniferous and broad-leaved trees, under the headings indigenous and introduced insects. Greater detail will be found in the 1969 Report of the Forest Insect and Disease Survey (Sippell *et al,* In press).

Indigenous Insects

Coniferous Hosts

The spruce budworm, *Choristoneura fumiferana* (Clemens), and its close relative, the jack-pine budworm, *Choristoneura pinus pinus* Freeman, dominated Survey activities throughout much of the year. As in 1968, the spruce budworm was present in outbreak numbers in three widely-separated parts of the province, west of Thunder Bay, in the Chapleau area, and in the Ottawa Valley. In 1968, an aerial spraying operation, covering 275,000 acres of forest west of Thunder Bay, was not completely successful in suppressing infestations near Burchell Lake. However, the outbreak was prevented from enlarging and spreading into adjoining areas, and a follow-up operation by the Ontario Department of Lands and Forests in 1969, during which 26,000 acres were treated with Fenitrothion, appears to have successfully eliminated the spruce budworm infestation. The two small new infestations north of the Ontario-Minnesota border in the Port Arthur district that caused moderate to severe defoliation appear to be unconnected with the Burchell Lake infestations.

An outbreak in northeastern Ontario that had its origin in the vicinity of Chapleau about 1967 intensified to cover roughly 2,800 square miles in 12 more or less distinct infestations ranging in size from a few square miles to over 2,000 square miles. The largest of these infestations lies mostly north and west of Highway 101 between Chapleau and Foleyet and west of the Ivanhoe River to the Dunrankin River crossing on the Canadian National Railway. To the west, an infestation straddles the Canadian National Railway between Peterbell and Fire River. Another large infestation lies north of Sudbury to the east of Onaping Lake. Only a small area has been exposed to at least three years of heavy defoliation, but host trees over more than 200 square miles have been severely defoliated for at least two consecutive years. On the basis of egg-mass counts, the outbreak is expected to increase in size in 1970, with extensions occurring mainly to the south and east of the large infested areas.

In the Ottawa Valley, infestations increased in intensity but not in extent, with white spruce suffering moderate to severe defoliation within an area of 1,200 square miles. Some of these infestations adjoin infestations in the Province of Quebec. Egg-mass surveys carried out in the fall of 1969 revealed extremely high numbers, and moderate to severe defoliation is expected in 1970 in susceptible stands between Petawawa and Pembroke. Many egg masses in this area appear to have originated from a mass influx of moths.

The widespread jack-pine budworm outbreak between Sioux Lookout and Kenora, which had persisted since 1966, collapsed, and only 10 square miles

of moderate to heavy defoliation remain north of Dryden. Aerial spraying operations with Fenitrothion at 4 ounces per acre were carried out north of Thessalon and Elliot Lake. This resulted in some reduction in the amount of defoliation, and since both infestations appear to be declining, only light defoliation is forecast for 1970.

The infestation in the Georgian Bay Provincial Park, west of Lake Nipissing, and along the French River, increased in both extent and intensity, and new pockets of heavy infestation were found on Manitoulin Island and in the north part of the Parry Sound district. Further moderate to severe defoliation is forecast for these areas in 1970. Infestations near Pembroke recurred as forecast in 1968 with an increase in extent and intensity in the Lake Traverse area and with other pockets of moderate to severe defoliation in the eastern part of Algonquin Park. Chemical control measures were applied in the Pembroke-Deep River area to protect high value stands in one instance and to minimize fire hazard in another. Better control was obtained in those areas receiving two similar applications of Fenitrothion for a total dosage of 8 ounces per acre than in those receiving a single application at 4 ounces per acre. In both cases, however, the objective was achieved. Since the Pembroke-Deep River infestation appears to be on the wane, only small pockets of moderate defoliation are forecast for 1970. However, populations in the Lake Traverse area are expected to be extremely high.

The balsam fir sawfly, *Neodiprion abietis* complex, caused browning and defoliation for the third consecutive year in the upper crowns of balsam fir in the Ottawa Valley from Mattawa to east of Arnprior. Some infestations coincided with those of the spruce budworm. Larvae of an unknown species of Cecidomyid were associated with severe needle-drop on the leaders of Scots pine in a plantation east of Smith Falls.

Broad-leaved Hosts

The most important insect attacking broad-leaved trees was the saddled prominent, *Heterocampa guttivitta* Walker, which caused heavy defoliation within a 900-square-mile area that extended from the western part of Algonquin Park across Highway 11 from Huntsville to Trout Creek. Some of the pockets of infestation reported in 1968 between Lake Simcoe and Georgian Bay and along the Bruce Peninsula persisted and new infestations occurred northeast of Oshawa. The forest tent caterpillar, *Malacosoma disstria* Hübner, defoliated aspen in two areas, one, west and north of Fort Frances, and the other, south of Elliot Lake. The forecast decline of the infestation around Fort Frances based on egg surveys made in 1968 did not materialize. This infestation is adjacent to one in the State of Minnesota. South of Elliot Lake, the area of defoliation decreased by half, and a further decrease is forecast for 1970. Two other aspen insects, a noctuid, *Enargia decolor* Walker, and the large aspen tortrix, *Choristoneura conflictana* (Walker), were found in much greater numbers throughout northern Ontario than in any year since 1963. *E. decolor* caused moderate to severe defoliation near Field and Mattawa and west of Kenora. The heavy infestation of the large aspen tortrix west of Port Arthur reported in 1968 enlarged, and other heavy infestations occurred along the shore of Lake Superior and between Sault Ste. Marie and North Bay.

A number of recurring defoliators of birch caused appreciable damage after having been present in low numbers for a number of years. Collections of the birch sawfly, *Arge pectoralis* (Leach), were much more numerous, and widely scattered light to heavy infestations were reported. This insect has been relatively scarce since the last outbreak between 1946 and 1954. Following collapse of the most recent outbreak of the birch skeletonizer, *Bucculatrix canadensisella* Chambers, in 1965, only very low populations of this species were reported until

1969, when small pockets of noticeable defoliation were detected by aerial surveys along the North Channel and along the east shore of Lake Superior. Finally, a birch sawfly, *Dimorphopteryx melanognathus* Rohwer, caused moderate to severe defoliation of yellow birch at many of the same locations north of Sault Ste. Marie, where infestations have erupted three times in the past 12 years.

A number of red oak insects were abundant at scattered locations across southern Ontario. These were: the oak skeletonizer, *Bucculatrix ainsliella* Murtfeldt, near Angus, Uxbridge, and Mallorytown; a tortricid, *Croesia semipurpurana* Kearfott, near Uxbridge and Orillia; and the oak leaf miner, *Lithocolletis hamdryella* Clemens, which caused severe leaf mining at numerous locations. The hickory tussock moth, *Halisidota caryae* Harris, has been a relatively scarce insect since 1945, until this year, when it defoliated butternut and walnut trees along the north shore of Lake Erie. Relatively high populations of the cottony maple scale, *Pulvinaria innumerabilis* Rathvon, persisted on soft maples in and around the city of Windsor. A rarely collected looper. *Melanolophia canadaria* Guenée, caused heavy defoliation of black ash in a small area north of Huntsville.

Introduced Insects

Coniferous Hosts

Long distance dispersal of the European pine sawfly, *Neodiprion sertifer* (Geoffrey), by the movement of infested nursery stock, was indicated once again by the finding of colonies of larvae feeding on ornamental pine in the city of Ottawa, well outside the main body of infestation. Elsewhere little change in its distribution was reported. Population levels were higher than usual in much of southern Ontario but epizootics of a polyhedral virus disease were frequently observed in plantations north of Lake Erie. The known distribution of the nursery pine sawfly. *Diprion frutetorum* (Fabricius), had not changed for a number of years until 1969, when larvae were collected near Huntsville; this indicates a northern extension in its range of about 25 miles.

Broad-leaved Hosts

The known distribution of the mountain ash sawfly, *Pristiphora geniculata* (Hartig), was extended appreciably to the north and west by collections made just east of Hornepayne and near Nagagamisis Lake Provincial Park on Highway 631 and west of Schreiber on the north shore of Lake Superior. These are surprisingly long extensions in the range of this sawfly when the scattered nature of its host tree is considered. It would appear that the area north of Lake Superior that has acted as a barrier to the westward spread of a number of other introduced insects has been breached. This sawfly is now expected to spread more rapidly into northwestern Ontario.

Fears of the gypsy moth, *Porthetria dispar* Linnaeus, spreading into Ontario from Quebec or New York State (Brown, 1969) were well-founded, since personnel of the Plant Protection Division of the Canada Department of Agriculture found egg masses of this pest on Wolfe Island near Kingston in the fall of 1969.

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II. INVITATION PAPERS

INSECTICIDE POLLUTION AND SOIL ORGANISMS[1,2]

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Abstract

Information available at present indicates that although residues of some organochlorine insecticides are accumulating in soils, they are not generally resulting in serious deleterious effects on soil microorganisms or soil animals. Some insect pests have become resistant to the cyclodiene insecticides, and also, population shifts have occurred, resulting in serious insect control problems. Plants are absorbing residues of some organochlorine insecticides from soils. While this does not appear to be a direct hazard to human health, the problem is potentially more serious with crops used for animal feed. Because of magnification, minute residues in crops may result in unacceptable residue levels in milk and animal products. The most serious problem is that of general environmental contamination with certain organochlorine insecticides and the side effects which may occur. Because of these side effects, the organochlorine insecticides are being rapidly replaced with organophosphorus and carbamate compounds, partly because of a popular misconception that these newer materials are less persistent. Data are presented to show that this is not necessarily the case. While advocating restrictions on the use of the organochlorine insecticides, the author suggests caution in haphazardly replacing them with materials which may have even more serious environmental side effects.

Although we hear a great deal about environmental pollution these days, the major emphasis is being placed on air and water pollution. Few people realize that there is a third aspect which is receiving less attention, i.e. pollution of the soil. Although we must have air to breathe and water to drink, it is from the soil that, directly or indirectly, we produce most of our food. The top few inches of the soil contain vast numbers of beneficial living organisms, which contribute to the structure, formation, and fertility of the soil. Without them the soil could conceivably become so unproductive that we would be unable to feed the exploding population of the world. Unfortunately, not all soil organisms are beneficial. Coleopterous, dipterous, and lepidopterous insects are serious crop pests, as are some other arthropods such as millipedes, mites and symphylans. Nematodes are a serious pest; fungi and bacteria cause diseases in plants; and weeds are an important problem. Consequently, modern agriculture injects large quantities of chemical pesticides into the soil to control these pests. What effects do these pesticides have on the soil organisms and their environment?

Although not entirely justified, much of the current concern over pesticide pollution of our environment is centred around insecticides. Consequently, this is

[1] Invitation paper presented as part of a symposium on "Pollution and the Entomologist" at the Annual Meetings of the Entomological Societies of Ontario and Canada, Guelph, Ontario, August 26-29, 1969

[2] Contribution No. 436, Research Institute, Canada Department of Agriculture, London, Ontario

the area of pesticide pollution about which we know the most, and to which I will restrict this discussion. However, I would like to suggest that many of the comments I make pertaining to insecticides may apply equally well to nematocides, fungicides or herbicides.

Before discussing the effect of insecticide residues in soils on soil organisms, it would perhaps be of value to review a little of the history of the use of insecticides in Canada and, using southwestern Ontario as an example, to illustrate the residue buildup in soil which has occurred.

Prior to 1945, insecticides in general use were inorganic compounds, of which lead arsenate was the prime example. This material was used extensively for many years, and is still used to some extent. Arsenic is highly persistent in soil and, as would be expected, residues have accumulated. Table 1 summarizes results obtained by Miles (1968) in a survey which he conducted on a number

TABLE I. Arsenic residues[1] in soils in southwestern Ontario in relation to crop grown

Crop	Average residue (ppm[2])	Lowest — Highest
sugar beets	3.7	1.5 — 8.6
corn	3.9	1.1 — 8.6
cereals	3.9	1.3 — 6.9
forage and pasture	4.0	2.9 — 5.5
tobacco	4.7	1.4 — 6.9
greenhouse vegetables	5.1	2.3 — 6.9
vegetables	5.4	1.1 — 26.6
orchards	53.5	10.2 — 121.0

[1] Arsenic occurs naturally in soils usually at < 10 ppm
[2] ppm calculated on the basis of the ovendry weight of soil

of farms in southwestern Ontario. Arsenic occurs in soils naturally, usually at concentrations of less than 10 ppm. Taking this natural arsenic content into consideration, it is apparent that most of our agricultural soils in Ontario do not contain significant levels of arsenic. However, in vegetable soils, arsenic residues were as high as 26.6 ppm, while in orchard soils, the residue levels ranged from 10.2 to 121 ppm.

DDT, the first synthetic organic insecticide, was introduced about 1945, and was followed in a few years by the cyclodiene insecticides, of which aldrin, dieldrin, heptachlor, and endrin are common examples. Between 1945 and 1965 these materials were used extensively for insect control. Their use has now declined drastically. DDT is highly persistent in soil, but is slowly degraded, primarily to DDE. Aldrin and heptachlor are only moderately persistent in soil, but are degraded in part to the persistent epoxides, dieldrin and heptachlor epoxide. Endrin, a steroisomer of dieldrin, is also persistent in soil. In 1964, we undertook a survey of the residue levels of organochlorine insecticides occurring in farm soils in southwestern Ontario. Residues were present in virtually all soils (Table II). The highest residue levels of DDT were found in tobacco, vegetable, and orchard soils. Residues of the cyclodiene insecticides, primarily dieldrin, were present in most soils with the exception of sugar beet soils, and orchard soils. Vegetable soils contained the highest residues of the cyclodiene insecticides. This study has been continued on a reduced scale on 16 farms. Between 1964 and 1966, residues of aldrin, dieldrin, and DDT increased while residues of endrin decreased (Table III). Five-year samples will be taken on these same farms in 1969. It is to be hoped that some levelling off of the aldrin, dieldrin, and DDT levels will occur to match the decreased use of the organochlorine insecticides which is said to have occurred since 1965.

TABLE II. Organochlorine insecticide residues in soils in southwestern Ontario in relation to crop grown

Crop	DDT and related materials (ppm[1])	Cyclodiene insecticides and related materials (ppm)	Total residue (ppm)
sugar beets	0.4	0	0.4
forage and pasture	0.5	0.3	0.8
corn	1.2	0.2	1.4
cereals	1.4	0.4	1.8
greenhouse vegetables	1.5	0.8	2.3
tobacco	3.2	0.6	3.8
vegetables	9.5	1.6	11.1
orchards	61.8	0	61.8

[1] ppm based on ovendry weight of soil

TABLE III. Average levels of organochlorine insecticide residues found in the soil on 16 farms in southwestern Ontario

Year	Organochlorine insecticide residues in soil (ppm[1])			
	aldrin	dieldrin	endrin	DDT
1964	0.25	0.48	0.22	17.4
1966[2]	0.47	0.78	0.12	23.9

[1] ppm based on ovendry weight of soil
[2] Further samples to be taken in September 1969

As a result of the development of cyclodiene insecticide resistance by some species of soil insects, and the persistence of some of the organochlorine insecticides in soil and other sectors of the environment, there has been a general trend away from these materials to other synthetic organics, primarily the organophosphorus insecticides and, to a lesser extent, the carbamates. The earliest organophosphorus and carbamate insecticides, such as parathion, malathion, diazinon, and carbaryl, were much less persistent in soil than the organochlorine insecticides. In our survey studies, we seldom find residues of these materials. Unfortunately, the limited persistence of these early substitutes has led to the development of a popular misconception that they are generally less persistent than the organochlorine insecticides. In fact, this is not necessarily the case. In our laboratory, we screen all experimental insecticides under controlled conditions to determine their persistence in soil, and the materials are classified into three groups: slightly residual; moderately residual; and highly residual. Over the past three years we have screened about 100 insecticides in this fashion. There are a number of short residual materials whose biological activity disappears in a matter of 2 to 4 weeks (Figure 1). However, there is a second generation of materials, many of which are now registered or close to being registered for use, which can be classed as moderately residual, i.e. they are similar in their persistence in soil to aldrin (Figure 2). At the rates at which they are recommended for use, which are often 2 to 7 times that required with aldrin, I have no hesitation in predicting that, in some instances, there will be a carry-over of residues of these materials in the soil from one year to the next. Even more disturbing is the fact that we have found some experimental insecticides to be *as persistent as dieldrin* (Figure 3), and at least one of these materials is being actively developed

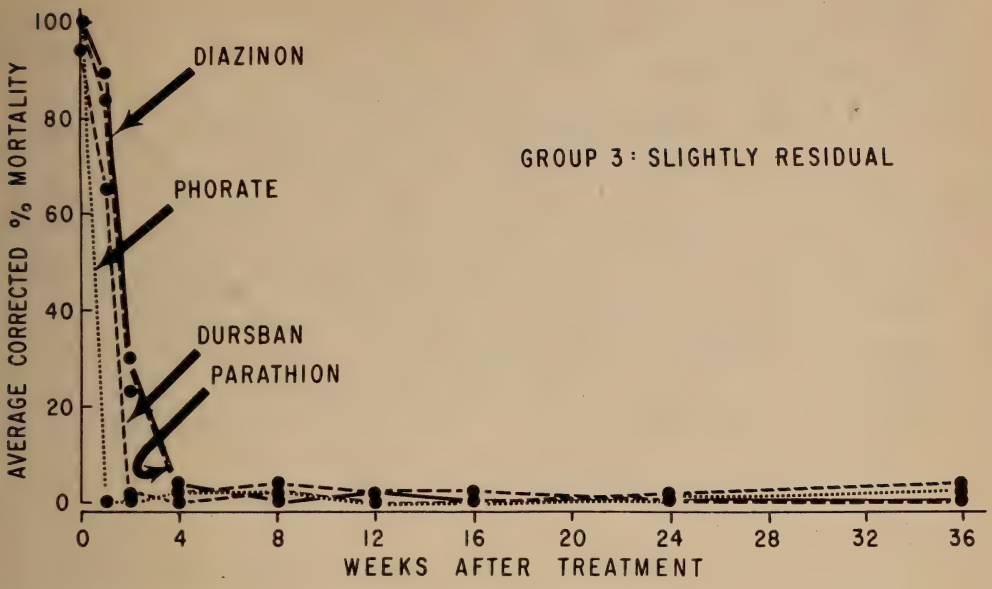

FIGURE 1. Persistence of biological activity of some insecticides in a sandy loam (Laboratory Studies)

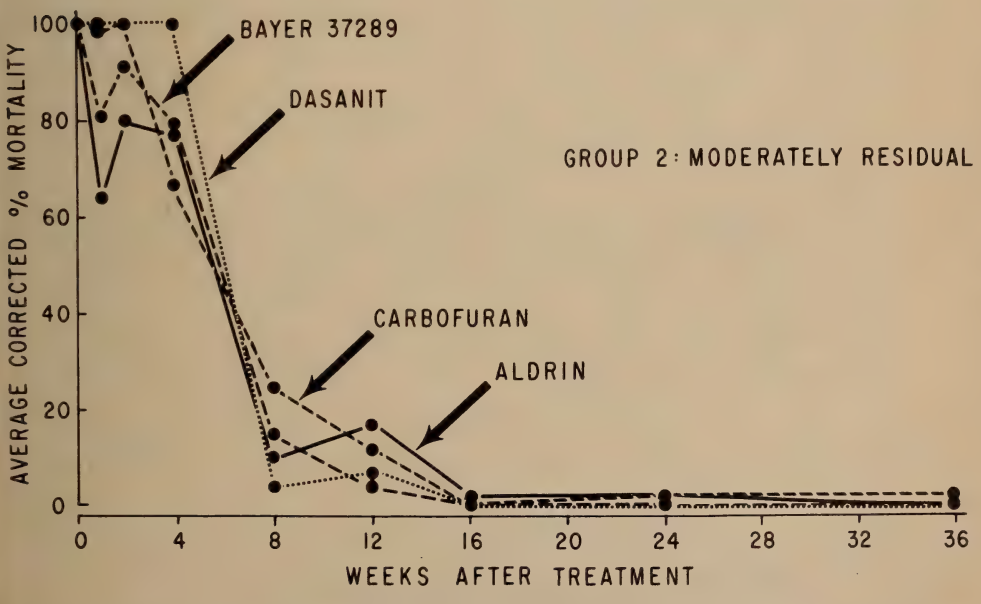

FIGURE 2. Persistence of biological activity of some insecticides in a sandy loam (Laboratory Studies)

for soil insect control. Thus, in our panic to move away from the persistent organochlorine insecticides, we are on the point of recommending materials

which are more hazardous to use, and may in themselves be as persistent as, or more persistent than, materials such as aldrin and heptachlor which have already been banned for use.

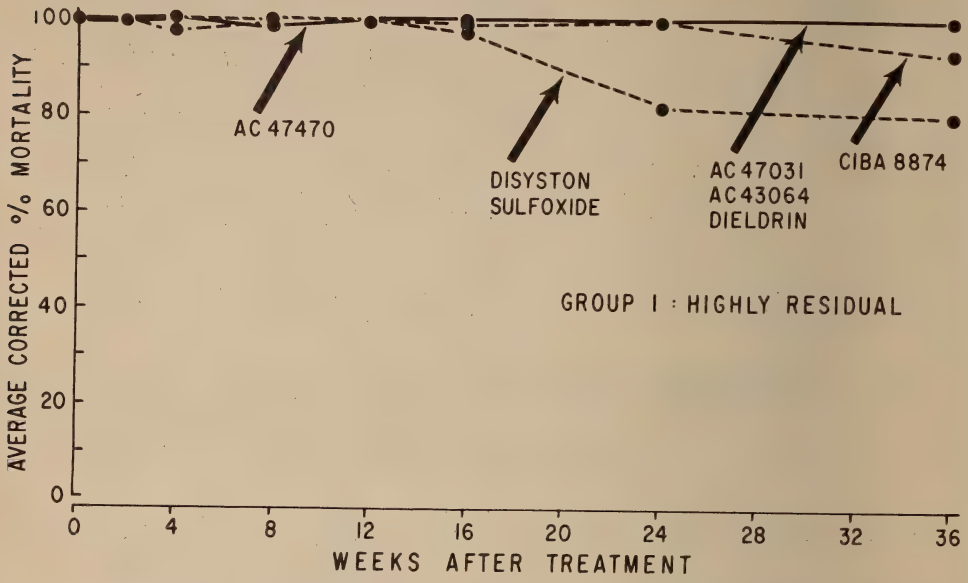

FIGURE 3. Persistence of biological activity of some insecticides in a sandy loam (Laboratory Studies)

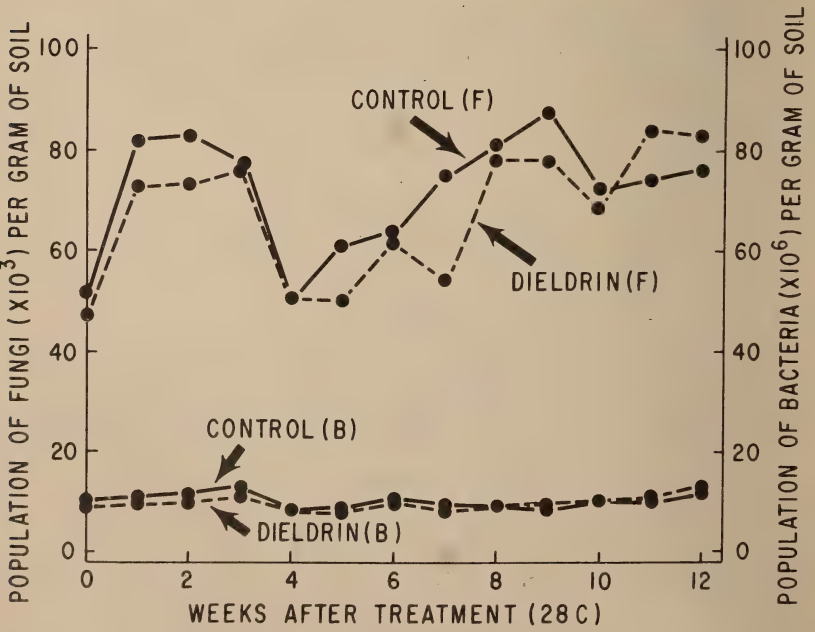

FIGURE 4. Influence of dieldrin (2000 ppm) on soil microorganisms

What effect then will these insecticide residues in soil have on the soil organisms?

Soil microorganisms are of primary importance to soil fertility. During the past three years, Dr. C. M. Tu at our laboratory has been studying the effect of insecticides on soil microorganisms. The effect of dieldrin on total counts of fungi and bacteria in soil is illustrated in Figure 4. This work was done at the excessively high concentration of 2,000 ppm, since the primary purpose of the experiment was to isolate a highly tolerant species capable of degrading dieldrin. However, dieldrin, even at this high concentration, had little effect on the total population of fungi and in fact, after 10 weeks, the population had adapted so well that the counts in the dieldrin treatment exceeded those in the control. Similar results were obtained with bacteria. Tu also obtained the same type of result with aldrin, and others have obtained similar results with heptachlor, heptachlor epoxide, and DDT. Thus it would appear that the organochlorine insecticides have little effect on soil microorganisms. Recently, Tu has been examining the effect of organophosphorus insecticides on soil microorganisms. Results (Figure 5)

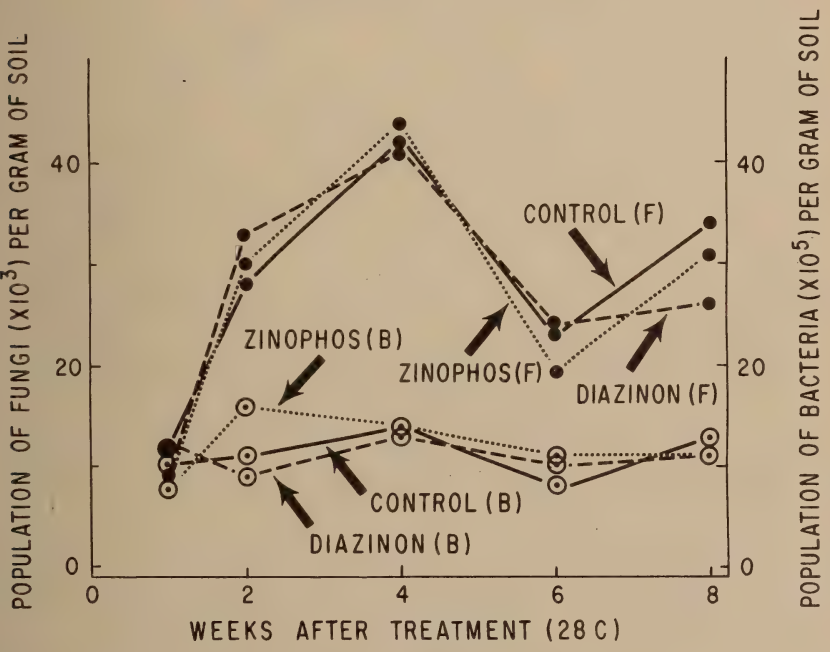

FIGURE 5. Influence of diazinon and Zinophos (100 ppm) on soil microorganisms

obtained with two organophosphorus insecticides, diazinon and Zinophos, both of which are commonly used for soil insect control in Canada, indicated that neither material at 100 ppm had any pronounced effect on either the fungal or bacterial populations in the soil. Tu has obtained similar results with several other experimental organophosphorus and carbamate insecticides which are being actively developed for soil insect control. Generally speaking, it would appear that the synthetic organic insecticides have little detrimental effect on soil microbial activities.

Although they have little effect on soil microorganisms, what effects do the microorganisms have on the insecticides? The two major cyclodiene insecticides

used in Ontario were aldrin and heptachlor, but the predominant cyclodiene insecticide residues in our soils are dieldrin and heptachlor epoxide. The explanation of this phenomenon is simple — the microorganisms convert aldrin to dieldrin and heptachlor to its epoxide. Recently in our laboratory, we isolated 92 species of soil microorganisms from a sample of soil taken from a farm in southwestern Ontario known to have had an extensive history of aldrin treatment. In *in vitro* experiments conducted over a period of six weeks, we found that 89 of the 92 species (97%) were able to convert aldrin to dieldrin in amounts ranging from a trace to 9.2% of the added aldrin, (Tu *et al,* 1968). The results obtained with two species of microorganisms are illustrated in Figure 6. In the one case, the conversion

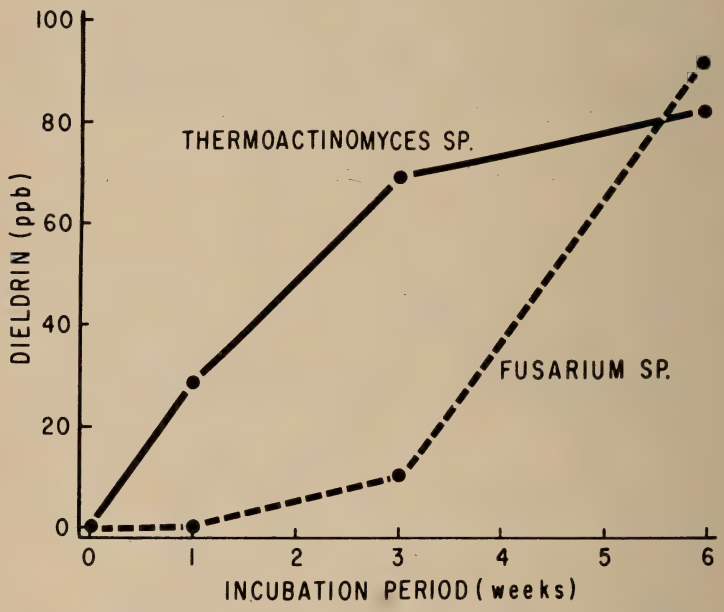

FIGURE 6. *In vitro* microbial conversion of aldrin to dieldrin

of aldrin to dieldrin began almost immediately. In the other instance, a period of adaptation was required before the organism could metabolize the aldrin. Both bacteria and fungi were capable of the conversion. However, the fungi appeared to be the most active converters. These results, then, explain the rapid disappearance of aldrin residues in soils, i.e. perhaps 90% of it will vaporize, while the remainder is oxidized by soil microorganisms to produce dieldrin.

Subsequent studies also pointed up another important difference between aldrin and dieldrin. Some soil microorganisms were capable of degrading dieldrin. Figure 7 illustrates the results obtained with two species capable of converting aldrin to dieldrin and, subsequently, degrading dieldrin, possibly to non-toxic hydrophylic metabolites. However, only 22 of 92 species (24%) of the soil microorganisms, primarily bacteria and actinomycetes, showed any ability to degrade dieldrin. Thus, the conclusion is obvious — so long as there are residues of aldrin in the soil, the microbial conversion of aldrin to dieldrin will be greater than the microbial degradation of dieldrin, and thus dieldrin residues will tend to accumulate in soil.

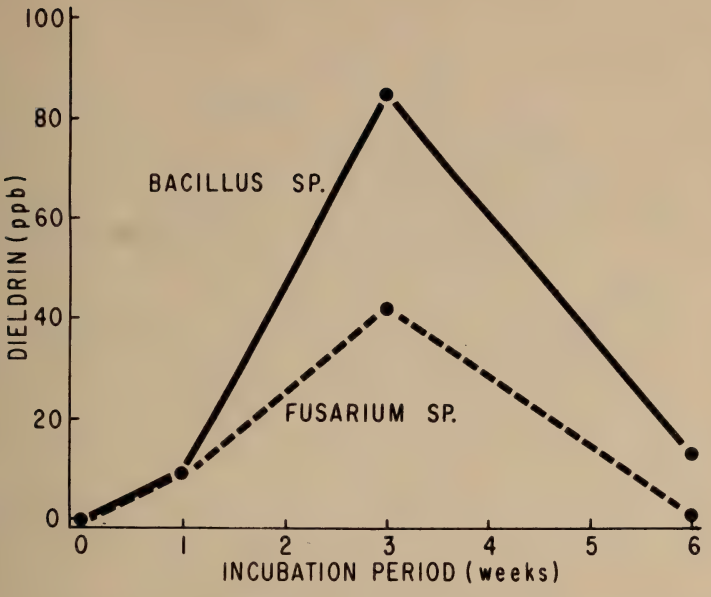

FIGURE 7. *In vitro* microbial conversion of aldrin to dieldrin and subsequent degradation of dieldrin

More recently we have been looking at the degradation of heptachlor by soil microorganisms and have obtained some extremely interesting and important results (Miles *et al,* 1970). The *in vitro* microbial and chemical degradation of heptachlor is complex (Figure 8). Heptachlor is volatile and a large part of it in water or soil will vaporize. In addition, we determined that microorganisms convert heptachlor to its epoxide and identified those involved. During the experiment we also found that a limited number of microorganisms are capable of degrading heptachlor to chlordene. And, we discovered a major pathway of chemical and microbial degradation of heptachlor to much less toxic metabolites. This involves the hydrolysis of heptachlor to 1-hydroxychlordene which is, in turn, metabolized by microorganisms to 1-hydroxy-2,3-epoxychlordene. This latter is then metabolized by microorganisms to an unknown compound, possibly ketochlordene. From the pollution point of view, these results are of considerable importance. The hydrolysis to 1-hydroxychlordene in aqueous solution occurs quite rapidly. Thus, it would appear that it is highly unlikely that heptachlor could become a serious pollutant of water. In soils, the picture is not quite so clear. While we have evidence that 1-hydroxychlordene is found in soils, the amount is about equal to the amount of heptachlor epoxide formed. At present we are trying to establish quantitatively the importance of the various pathways of degradation of heptachlor in soil, soil-water, and water systems.

Microorganisms also degrade DDT to DDE and some evidence is now being accumulated that indicates that they are active at some stage in the degradation of organophosphorus and carbamate insecticides. It is becoming apparent that soil microorganisms have a major role in the degradation of insecticidal residues in soil.

What are the effects of insecticides on soil animals? Soil animals belong primarily to three invertebrate phyla, the Protozoa, Annelida, and Arthropoda. Of

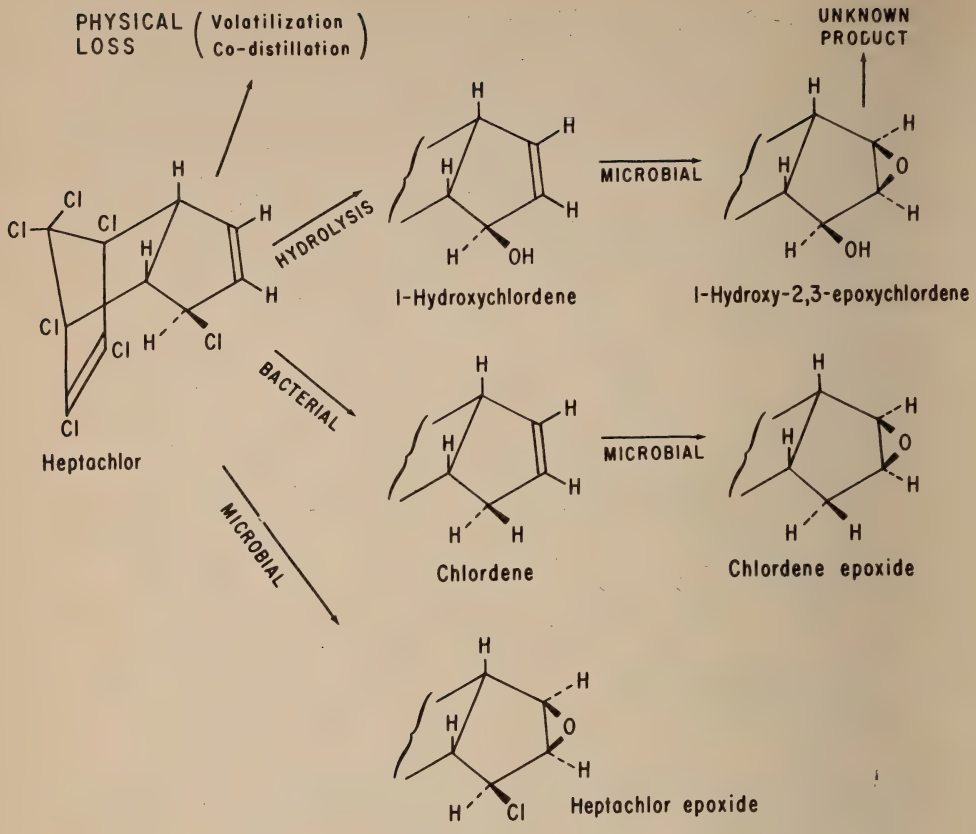

FIGURE 8. Scheme for chemical-microbial degradation of heptachlor

these, little is known of the effects of pesticides on the soil protozoans. Fortunately, some excellent work is being carried out by Dr. C. A. Edwards and his co-workers at Rothamstead on the effects of pesticide residues in soil on other soil invertebrates, and in a recent paper Edwards (1969) summarized the results of several years of research.

Earthworms are of major importance in soil since they break down much of the plant debris reaching the soil, and turn over the soil and aerate it. Thus, pesticide residues in soils which appreciably reduce numbers of earthworms could constitute a serious problem. Edwards has shown that earthworms are tolerant to many pesticides. None of the chlorinated hydrocarbons affected them seriously, other than heptachlor and chlordane. Among the common organophosphorus and carbamate insecticides, only phorate and carbaryl were particularly toxic. Other organophosphorus insecticides did reduce earthworm populations, but they recovered relatively quickly since the chemicals were all short-residual compounds. However, it is difficult to predict what will happen to earthworm populations with the second generation of organophosphorus and carbamate insecticides now being developed for use. These materials, which are moderately persistent in soil, may have a more lasting effect. I do think that it is significant, however, that the materials which have had the most toxic effect on earthworms, i.e. chlordane, phorate, and carbaryl, are three materials that are commonly being substituted in place of the organochlorine insecticides that are being phased out.

An equally important aspect of the earthworm problem is that they can concentrate the organochlorine insecticides in their adipose tissue. Edwards has found aldrin and dieldrin residues in the bodies of earthworms at concentrations 10 × that of the surrounding soil. Similar results have been obtained with heptachlor, heptachlor epoxide, and DDT. Such uptake of these persistent insecticides constitutes a serious problem, since earthworms serve as an important source of food for birds, which in turn may concentrate insecticides to an even greater degree. Hence, earthworms, as a lower link in the food chain, are an important source of undesirable chemical residues in higher animals. Fortunately, Edwards has found that the less residual organophosphorus insecticides are not concentrated to any great extent in earthworms. More information is required on the second generation organophosphorus and carbamate insecticides now being developed.

Edwards and his group have concentrated much of their effort on soil arthropods. Many soil arthropods are beneficial in that they contribute to the disintegration and digestion of plant residues, and to the breakdown of debris into its organic and inorganic constituents. Examples include the wood lice, millipedes, oribatid mites, and several species of insects, particularly springtails and larvae of beetles and flies. Other arthropods, including millipedes, mites, symphylans, and lepidopterous, coleopterous and dipterous larvae are serious pests. Still others, including spiders, centipedes, and parasitic mites are predatory on both the beneficial and pest species of soil insects. Recently Edwards (1969) summarized results of an interesting study on the effect of DDT and aldrin applied at normal rates of soil application on soil arthropods. As would be expected, both pesticides radically altered the number of individuals within the population of each species of soil arthropod, and also the number of species present in the soil. The overall effects obtained are illustrated in Figure 9. DDT resulted in a slight decrease in total arthropod weight, while aldrin resulted in a drastic decrease. When predator weights were compared, both DDT and aldrin drastically reduced the soil predators. However, when the beneficial arthropod weights were compared, DDT resulted in an increase over the control, while aldrin resulted in a sharp decrease. Edwards showed that the increase in beneficial arthropod weight obtained with DDT was because DDT was toxic to predatory mites, and as a result a pronounced increase in Collembola occurred. Since Collembola are of major importance in the degradation of plant debris to organic matter, it is apparent that DDT, in this instance, has a beneficial influence. As would be expected, both aldrin and, to a lesser extent, DDT, resulted in a drastic decrease in pest weight. The results with aldrin would seem to indicate that, in contrast to DDT, it has a pronounced deleterious effect on both predators and beneficial soil arthropods, as well as on the arthropod pests. However, this particular series of experiments was conducted on soils which were not cultivated. When Edwards ran parallel experiments with control and aldrin plots on cultivated and uncultivated soil, he found that cultivation alone reduced the soil arthropods to an extent similar to that obtained with aldrin. He concluded that the change produced by aldrin was not significant in terms of soil fertility. The general conclusion which he has reached from his studies is that it is only in forest and woodland soils that insecticide pollutants are a potential hazard, in that they may slow down the processes of soil formation and maintenance of soil fertility. He suggests that aerial spraying with large quantities of pollutants in forests should be eliminated wherever possible.

As shown in Figure 9, both aldrin and DDT markedly reduce arthropod pest populations. The most effective materials against the common insect pests in soil were aldrin and the other cyclodiene insecticides. As a result these materials were used extensively across Canada and the United States, and, as shown earlier (Tables II and III) cyclodiene insecticide residues have built up to significant levels in soils,

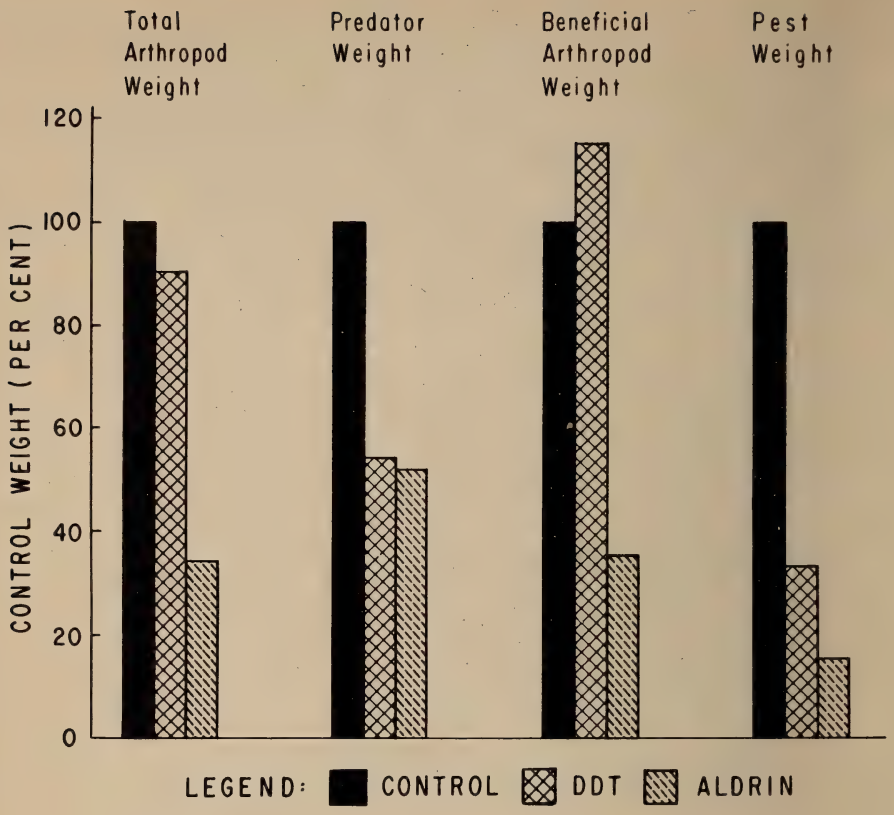

FIGURE 9. Influence of DDT and aldrin on soil arthropod populations [Modified from C. A. Edwards (1969)]

particularly tobacco and vegetable soils. In many instances, these residue levels were sufficiently high to result in constant selection pressure on soil insect populations. Consequently, within a relatively short period of time some soil insects developed a high degree of cyclodiene insecticide resistance. In Canada this was particularly the case with the root maggots (Table IV). Five species developed

TABLE IV. Degree of cyclodiene insecticide resistance to aldrin in various species of root maggots in southwestern Ontario

Species	Resistance level
bean seed fly (seed maggot)	× 255
onion maggot	× 591
seed-corn maggot (seed maggot)	× 770
cabbage maggot	× 1,127
carrot rust fly	× 5,600

a very high level of resistance to aldrin, ranging from × 255 with the bean seed fly to × 5600 with the carrot rust fly. In addition, cross-resistance occurred to all the other cyclodiene insecticides, but not to DDT or the organophosphorus

or carbamate insecticides. In the United States, wireworms and the corn rootworm have also become resistant to the cyclodiene insecticides. The use of these materials has also resulted in species shifts which have resulted in serious economic problems. A good example of this is the cutworm problem in tobacco in southwestern Ontario. In the 1950's the major cutworm species in tobacco were the black (*Agrotis ipsilon* Hufnagel), and variegated (*Peridroma saucia* Hübner) cutworms. The dark-sided cutworm (*Euxoa messoria* Harris) was a pest of minor importance. By 1957, aldrin and heptachlor were being used extensively for cutworm control in tobacco. These materials were remarkably effective against the black and variegated cutworms (Table V), and when applied at the recommended rate of 1½ pounds per acre, provided 100% control. Within 2 to 3 years both species had ceased to be a problem. However, the dark-sided cutworm was highly tolerant to aldrin (Table V) and the other cyclodiene insecticides, and as the

TABLE V. Toxicity of aldrin EC applied as a surface application to moist sandy loam to 3-4 instar larvae of the variegated, black and dark-sided cutworm

Species	Average corrected % mortality at indicated rate of application (pounds active ingredient per acre)				
	¼	½	1	2	4
variegated	94	100	100	100	100
black	45	95	100	100	100
dark-sided	0	0	0	0	0

two susceptible species were eliminated, the dark-sided cutworm moved in to fill the vacuum. By 1961, the outbreak reached extremely serious proportions, and it was not until 1966 that an adequate method of control was worked out utilizing DDT. An intensive research program is now under way to find adequate replacements for DDT.

To date, there has been no development of resistance to the organophosphorus insecticides by soil insects in Canada although the corn rootworm has become resistant to diazinon in the United States. The main criteria for the development of organophosphorus insecticide resistance is the same as that which was necessary with the cyclodiene insecticides, i.e. that residues in soil should be sufficiently high to result in constant selection pressure on the population. So long as we use short residual organophosphorus insecticides such as diazinon, it is unlikely that this will occur, other than with insects which have only one generation per year. However, in some instances, these short residual materials have not provided effective pest control. As a result we are beginning to switch to more residual organophosphorus and carbamate insecticides (Figure 2). These materials will undoubtedly result in higher selection pressure, and, in 5 to 6 years, I would expect that we will begin to see the development of organophosphorus insecticide resistance in certain species of soil insects, particularly the cabbage maggot. In addition, we may also encounter population shifts similar to those I described with cutworms. The substitute materials which we are developing to replace DDT for cutworm control are short residual materials. While they will be effective against the dark-sided cutworm, they will not necessarily be effective against the black and variegated cutworms. Within 4 to 5 years after their introduction, we may find that the dark-sided cutworm is no longer a problem, while the black and variegated cutworms are ascendant.

In any discussion of soil pollution we cannot ignore the effects of pollutants on the plants we grow in the soil. The most obvious effect is phytotoxicity. With insecticides this has happened in some instances where attempts have been made

to convert orchards to other types of farming. Arsenic at high concentrations, as occurs in orchards, can be phytotoxic to some crops. A less obvious but more important effect is that residues are absorbed from soils by some crops. Root crops are often quoted as the prime examples of this phenomenon. Table VI shows

TABLE VI. Residues of organochlorine insecticides in a clay loam soil and residues found in root crops grown in this soil

Soil-Crop	Organochlorine insecticide residues (ppm[1])		
	DDT	aldrin	dieldrin
Soil — before planting	0.36	0.53	0.88
— after harvest	0.34	0.48	1.08
Carrots	T[2]	0.02	0.11
Radishes	T	T	0.05
Turnips	0	0	0.03
Onions	0	0	0.02

[1] ppm calculated on ovendry weight of soil and fresh weight of crop
[2] T = trace = < 0.01 ppm

residues of DDT, aldrin, and dieldrin absorbed by root crops grown in a clay loam soil contaminated with these three insecticides. The amounts of DDT absorbed by crops are generally insignificant. Contrary to popular opinion aldrin is not absorbed by crops to any significant extent, or if it is, it is rapidly converted to dieldrin. Significant dieldrin residues appear in root crops, particularly carrots (Table 6). However, the indications are that residues absorbed by crops used for human consumption are generally well below the established tolerances.

More serious is the problem of absorption of some insecticide residues from soil by crops used for animal feed (Table VII). Residues of DDT and aldrin did

TABLE VII. Residues of organochlorine insecticides in a clay loam soil and residues found in crops used for animal feed

Soil-Crop	Organochlorine insecticide residues (ppm[1])		
	DDT	aldrin	dieldrin
Soil — before planting	0.39	0.37	1.02
— after harvest	0.43	0.14	1.19
Sugar beets (roots)	0.01	0	0.07
Carrots	0	0	0.04
Potatoes	0	0	0.03
Sugar beets (tops)	0.03	0	0.03
Corn	0.04	0	0.02
Oats	0.03	0	0.02
Alfalfa	0.01	0	0.02

[1] ppm calculated on ovendry weight of soil and fresh weight of crop

not appear in what would be considered significant amounts. However, virtually all the crops tested absorbed dieldrin to some extent. Sugar beets absorbed the greatest amounts, followed by carrots, potatoes, sugar-beet tops, corn, oats, and alfalfa. Since animals tend to concentrate dieldrin in their fatty tissues, this constitutes a potentially serious problem. There is little agreement as to the concentration of dieldrin in crops which will result in unacceptable residue levels in milk and other animal products. Obviously, this will depend on a number of factors

including the dieldrin concentration in the crop, the proportion of the crop in the animal diet, and the length of time that the crop in question is fed to the animals. It is often assumed that levels as low as 0.02 ppm of dieldrin in a crop would result in unacceptable residue levels in milk and animal products. On this basis, which is admittedly rather arbitrary, it would appear that in a number of instances in our experiments, residues of dieldrin in the soil were sufficiently high to result in significant residue levels in crops grown for animal feed. However, I should point out that we were working with soils in which the cyclodiene insecticide residues were abnormally high, and that, as a general rule, most of our agricultural soils contain less than one-third that amount of residue.

I am often asked, "What level of insecticide residue in the soil constitutes pollution?" This is an extremely difficult question to answer. Unfortunately, many people tend to take the results of chemical analysis *per se* and make a judgment on this basis. This is the wrong approach. Table VIII shows results we

TABLE VIII. Influence of organic content of soil on the biological activity of dieldrin and its absorption by carrots

Soil type	% O.M.	Dieldrin (ppm[1]) in soil	Dieldrin (ppm[1]) in carrots[2]	Bioactivity[3]
sandy loam	1.0	1.77	.20	97
clay loam	6.1	1.91	.04	6
clay loam	29.4	1.76	.01	2
muck	41.7	2.00	.01	0
muck	70.0	1.99	.01	0

[1] ppm based on ovendry weight of soil and fresh weight of crop
[2] tolerance = 0.1 ppm
[3] test insect = first instar crickets

obtained when we grew carrots in soils containing approximately the same concentration of dieldrin (2 ppm) but varying amounts of organic matter. As you can see, both the insecticidal activity assessed by bioassay and absorption of the residues by crops decreased in proportion to the amount of organic matter in the soil. Thus, a residue of 2 ppm of dieldrin in a sandy loam would constitute a fairly serious level of pollution. By contrast, 2 ppm of dieldrin in a muck soil is of little consequence. Most of our high insecticide residues, incidentally, occur in muck soil where they are inactivated. We seldom find a mineral soil where residues of dieldrin exceed 0.5 ppm or, at the very most, 1 ppm. We have obtained similar results with both heptachlor epoxide and DDT in that activity and/or absorption by crops is in proportion to the amount of organic matter in the soil.

To sum up: The information which we have to date, which deals primarily with the organochlorine insecticides, indicates that the present residue levels in soil are generally not resulting in any serious deleterious effects on beneficial soil organisms. The organochlorine insecticides do not effect soil microorganisms and hence are not altering soil fertility; with one or two exceptions, they are not causing permanent deleterious effects on beneficial soil animals. On the other hand, some insect pests have become resistant to the cyclodiene insecticides, and in other instances, population shifts have occurred, resulting in serious insect control problems. Also, some plants are absorbing residues of some cyclodiene insecticides from soil. While these residues are not at serious levels in crops for human consumption, the problem is potentially more serious in crops used for animal consumption.

At present there is a trend away from the persistent organochlorine insecticides to organophosphorus and carbamate insecticides, on the questionable as-

sumption that these materials will have less serious side effects. Unfortunately, this trend to the newer materials is developing into a stampede which, in the end, could result in even more serious problems than we have at the present time. I say this for a number of reasons. First, as I pointed out, there is a popular misconception that the newer materials are less persistent in soil, and this is not necessarily the case. Secondly, while most organochlorine insecticides are almost insoluble in water and do not move vertically downward in soil to any great extent, many of the newer materials are slightly to moderately soluble so that, consequently, we run the risk of contaminating ground water, as well as streams and lakes. Third, these newer materials are usually more toxic to handle and can be as toxic, or more toxic, to beneficial soil animals, fish and wildlife. Fourth, while considerably more expensive, they do not provide the same degree of insect control as the organochlorine insecticides. By switching to them, we are deliberately decreasing crop yield or quality. Thus, I feel that the organochlorine insecticides still have an important place in some phases of insect control.

At the same time we cannot ignore the problem of environmental pollution. Although this problem has been blown up out of all proportion by the opponents of pesticides, there is sufficient information available to indicate that the persistent organochlorine insecticides are, indeed, a serious problem. The evidence, however, is that, in most instances, the problem is not coming so much from agricultural operations as from municipal uses, such as massive Dutch elm disease control programs and home owner use, and from rural programs, such as biting fly control in recreational areas. I strongly advocate that the use of the organochlorine insecticides should be banned for these purposes, and that their use in agricultural and medical entomology should be restricted to those situations where the use is absolutely essential and where it can be demonstrated that this use is not resulting in a serious environmental pollution problem. Such applications should be by permit only.

In conclusion, I would like to state quite bluntly that we cannot do without pesticides. We need them to produce, store, and process our food; to protect vast areas of forest; to protect man and his animals against disease-carrying insects; to treat imported food and fiber to prevent the introduction into Canada of undesirable species of foreign pests; and to provide control of nuisance pests, e.g. mosquitoes and black flies, so that man can enjoy his leisure time. In recent years there has been a great deal of publicity and discussion over non-pesticide methods of controlling pests, such as biological control. The simple fact is that, other than in isolated instances, present non-pesticide approaches are impractical, expensive or require much more research before they might be developed to a practical level. It appears that pesticides will be with us for a long time. Their assets greatly outweigh their liabilities. We must simply learn how to use them properly, and how to regulate and control their use.

Chemical Designations of Experimental Materials

American Cyanamid AC43064: cyclic ethylene (diethoxyphosphinothioyl) dithioimidocarbonate
American Cyanamid AC47031: cyclic ethylene (diethoxyphosphinyl) dithioimidocarbonate
American Cyanamid AC47470: cyclic propylene (diethoxyphosphinyl) dithioimidocarbonate
Bayer 37289: 0-ethyl 0-2,4,5-trichlorophenyl ethylphosphonothioate
Ciba 8874: 0-(2,5-dichloro-4-iodophenyl) 0,0-diethyl phosphorothioate
Dasanit: 0,0-diethyl 0-p-(methylsulfinyl) phenyl phosphorothioate
Disyston sulfoxide: 0,0-diethyl S-2-(ethylsulfinyl) ethyl phosphorodithioate
Dursban: 0,0-diethyl 0-3,5,6-trichloro-2-pyridyl phosphorothioate

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ECONOMICS AND PESTICIDES

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Abstract

The complicated web of relationships among components of the environment tends to amplify effects of environmental pollution. Degradation of the environment increases overall costs and may eliminate desired options of management necessary for a healthy, productive worldwide environment.

Pesticides are not the most serious environmental pollutants, although they are probably the most toxic pound for pound. The question is not whether they are undesirable, but how serious are they as pollutants. There is a paucity of conclusive data. The essence of the problem is that pesticides, though only one facet, represent an increasing concern for the effects of man's irreversible modification of his environment and recognition for stocktaking.

The consequences of pesticide use are vaguely discernible, yet authorities must develop overall policy for the environment that will integrate conservation, agriculture, human health, economic development, and other factors, and which will provide for choice when objectives are incompatible. Accelerated research in physical, biological and social sciences must result in organized and correctly interpreted data. Increased ecological understanding coupled with an analytical approach to cope with complex systems is necessary.

There are several economically related concepts within the context of pesticide pollution with which entomologists should be concerned. (1) The risk versus benefit controversy may be reduced by economic analysis, that is, the comparison of gains and losses to the well-known cost equation. (2) Use of integrated control systems in which there is a deliberate blending of different control techniques within the framework of the lowest tolerable pest damage level deserves increased utilization. (3) Centers of multidiscipline competence are needed to improve the efficiency (accuracy) of pesticide application to reduce environmental contamination by pesticides. (4) Pesticide use can be reduced by avoiding large acreages of a single crop in which opportunistic species may develop explosively without inhibition by a diversity of habitat.

(5) The accumulation of needed information through national and international monitoring of components of the environment deserves active support.

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Definition of the Environment

Commoner (1967) has explained that the community of life in the environment — the biosphere — is enormously complex and that this complexity is the source of its remarkable power. The web of relationships that ties animal to plant, prey to predator, parasite to host, and all to the air, water and soil which they inhabit persists *because* it is complex.

According to Commoner, the biosphere is closely governed by the connections among its numerous parts. The connections which comprise the biological food chain greatly amplify the effects of environmental pollution. If soil contains one unit of insecticide per gram, earthworms living in the soil will contain 10 to 40 units per gram, and in woodcocks feeding on the earthworms the insecticide level will rise to about 200 units per gram. In the biosphere the whole is always greater than the sum of its parts; animals that absorb one insecticide may become more sensitive to the damaging effects of a second one. Because of such amplifications, a small intrusion in one place in the environment may trigger a huge response elsewhere in the system, he suggests. It is not surprising, then, that the introduction of any killing chemical into the environment is bound to cause a change somewhere in the tangled web of relationships. For this reason, and because we depend on so many detailed and subtle aspects of the environment, *any* change imposed on it for the sake of some economic benefit, has a *price*. For the benefits of powerful insecticides we pay in losses of birdlife and fish. For the convenience of automobiles we pay in the rise of respiratory disease from smog. Dr. Commoner concludes that sooner or later, willingly or unwillingly, we must pay for every intrusion on the natural environment.

The Daddario Subcommittee Report, "Managing the Environment" (Anonymous 1968a) states that, in truth, man *is* managing the environment today. The world's population is already great enough to necessitate a careful and methodical approach to the environment if all men are to achieve a reasonable standard of living. Population pressures will increase for many years to come, subjecting the environment to heavier usage in the future than in the past. Degradation of the environment increases overall costs and may eliminate desired options of management. A high quality environment is also the most efficient environment in serving man's needs. Thus the long-term support for civilization must be based on a farsighted management of a healthy, productive worldwide environment. The two are incapable of separation.

The Relative Role of Pesticides as Pollutants

Before discussing pesticides as pollutants, we must recognize their relative importance in order to put them in proper perspective with other pollutants from municipal and industrial sewage, animal wastes, urban solid wastes, mining wastes, and consumer goods wastes. Pesticides are *not* the most serious pollutants of our environment as a few people would have us believe. From the standpoint of injury to health and survival of man and his domestic animals and wildlife, pesticides are far down the list in priority of importance for corrective measures. The Great Lakes are frequently referred to as classic example of pollution. Yet "The Lake Erie Report" (Anonymous, 1968b), by the U.S. Federal Water Pollution Control Administration, covers the pesticide problem in one short sentence. In articles on pollution in the Lakes, an issue of *Audubon* (Chiappetta, 1968) and an issue of *Life* (Woodbury and Eisenstaedt, 1968) were similarly brief in their mention of pesticides.

An ecologist, Dr. Donald Spencer (1969) says that so much attention is given to pesticides as the most important pollutant — which he emphatically contends is untrue — because other sources of pollution present problems that

are more difficult to solve and draw less public support. The Federal Water Pollution Control Administration report entitled "Pollution Caused Fish Kills" (Anonymous 1968c), issued annually since 1960, attempts to document all the known causes of fish kills in the United States. The latest report, covering the year 1967, shows that of the 11 million fish killed, only 2.9% of the kills were caused by insecticides of all types. Reduced oxygen content, resulting from manure and silage drainage, killed four times more fish than pesticides. Spencer has noted that even relatively small changes in the local environment of fish and widlife may cause their disappearance. Thermal pollution — as little as 3°F — may cause heavy mortality; alkalinity, acid mine drainage, salinity, and metallic salts are other important factors.

Newson (1967) has stated that about 5% of the total land area of the United States is treated each year at the average rate of 2.5 pounds of insecticide per acre. Much of the 90 million acres treated is in fertile alluvial areas adjacent to streams, lakes, and ponds where carelessness in application, drift, and runoff may allow substantial amounts of insecticides to get into water systems. Water erosion of soil particles to which insecticides have been adsorbed, with subsequent transport into streams by surface runoff, accounts for significant contamination of water systems. Newsom cites several studies in which chlorinated hydrocarbon pesticides at recommended rates did not result in the accumulation of large amounts of residues in the soil; it would be improbable that accumulated residues would ever exceed the amount applied during one year.

Newson (1967) concludes that three consequences of pesticide use are likely to result in more good to mankind than all of their adverse effects combined. They are: (1) stimulating the development of concepts of pest control that transcend the parochial interests of entomologists, wildlife specialists, public health workers, and conservationists; (2) convincing applied biologists of the necessity for developing pest control techniques based on ecological principles; and (3) arousing scientists and the public to an awareness of the overall problems of environmental pollution.

As a group, pesticides are probably among the most toxic pollutants, pound for pound. This is why they are so useful. The question about their nature as pollutants is not whether they are undesirable, but how serious are they? It is now possible to measure concentrations of pesticides in air on the order of one part per billion. In the air monitoring effort just commencing, we are not at all sure that there will be a high percentage of positive samples. Most of our water monitoring effort has centered on surface river water. Significance of pesticides probably lies not so much in concentration as in their distribution and resultant biological effects. More useful data would concern their abundance on suspended particles that are ingested by microorganisms and thus enter the food chain. Significance is not always apparent. As much effort has probably been devoted to monitoring for pesticides in soil as in any other section of our environment. As in the case of water, the pesticide content of a rather large proportion of soil samples is below the detectable level.

How important are pesticides as environmental pollutants? The amount of available scientific data on which to base conclusions is less than we should have. But some reports (Stickel, 1968) (Porter and Weimeyer, 1969) are being received on rather thorough studies that bridge the gap between preliminary laboratory work with test organisms and the suspected facts of the case.

Recent attempts to deal with the problem of the relationship between smoking and lung cancer illustrate a pertinent point which parallels our response to reports of damage to the environment. As one Government report (Anonymous, 1968a) put it, the evidence that smoking can cause lung cancer is insufficient for direct prohibitive legislation. Other factors *can* be responsible, and the circumstantial,

statistical nature of the evidence can never be equal to the classical adage of one agent = one disease. This example shows that causes which are separated from effects by long time periods, or by intricate mechanisms or a multiplicity of interactions, constitute a class of hazards which confound the protective role of Government.

Smith (1968), Director of Cooperative Extension at Cornell University, wrote: 'The time factor is one for concern. We cannot program research on a time schedule with certainty, nor do we know how much lead time we have. Certainly every effort should be made to reduce the input of objectionable pesticides to a minimum and bide our time with less objectionable materials. We should concern ourselves with the total production of persistent pesticides and where they are introduced into the ecosystem. We must not assume that their use at distant points is of no concern."

There are those who would take a more direct tack. Niering (1968), Director of the Connecticut Arboretum, asks this question: ". . . is it really good business to reduce the use of pesticides? Will biological control make as much money? Here the problem integrates political science, economics, sociology and psychology. Anyone seriously interested in promoting the sound use of biocides must be fully cognizant of these counter forces in our society. They need serious study, analysis and forthright reporting in the public interest. With all we know about the deleterious effects of biocides on our environment, the problem really challenging man is to get this scientific knowledge translated into action through the socio-political pathways available to us in a free society. If we fail to communicate a rational approach, we may find that technology has become an invisible monster . . ."

The essence of the problem is well stated in the comprehensive report to the U. S. Congress called "Pesticides and Public Policy" (Anonymous, 1966): "The public debate over pesticides is but one facet of a wider debate which reflects a greater sensitivity to the fundamental questions raised by the continuing and accelerating pace of man's modification of his total environment. Pesticides are but one factor and we are increasingly aware that our environment is being altered even more dramatically by air and water pollution, atomic fallout, and population explosion. These are manifestations of the great issues of our time — man's relationship to the world around him. As we come to appreciate more keenly the significance of this vast, accelerating, irreversible alteration of our environment, we recognize the need for stock-taking and the necessity of endeavoring to take into account all the multitude of complex relationships between man and his natural and artificial surroundings."

Policies and Plans for Correction

Most authorities agree that pesticides will continue to be needed. *Chemical Week* (Neumeyer, Gibbons, and Trask, 1969) states: "A dynamic growth in pesticide production and application in the next 5 to 10 years is expected." There is much less agreement as to what policies and plans should be developed and followed in assuring that pesticides will not be used to the detriment of the environment. I'd like to discuss policies and plans.

The Subcommittee on Science, Research and Development that produced the previously mentioned report, "Managing the Environment" (Anonymous, 1968a), noted a sequence of public opinion, political action and corrective measures which is common to most pollution problems, as follows:

1. *Apathy:* The subtle nature of environmental quality problems makes it possible for effects to become quite advanced before the public becomes aware of them.

2. *View with Alarm:* The early stages of quality loss often are noticed by naturalists, recreation enthusiasts, and scientists who worked in the outdoors. Often the alarm is exaggerated (purposely or not), and a negative response is obtained from other observers who do not view the trend as serious. The public information system of scientists, media, and officials cannot always produce an objective report. A scientist may find an obscure, little-understood anomaly in a highly sensitive, delicate ecosystem. He proceeds to speculate imaginatively that irreversible, disastrous results might occur. The mass media remove whatever limitations or caveats may have been attached to these speculations.

3. *Episodes Occur:* An air pollution attack or mysterious fish kill brings scientists into the problem and gains the attention of the public. This attention can then be used to elaborate on the long-term possibilities and to cultivate a desire for control of the environmental hazard.

4. *Monitoring and Source Identification:* Officials and scientists want to understand cause and effect. Monitoring is usually inadequate.

5. *Human Health Effects:* From the dogma that pollution "can't be good for you" comes the obvious goal of returning to a pristine environment.

6. *Public Cry for Action:* Public opinion is now aroused and there is a thirst for information and explanation which often cannot be met with the facts at hand. The leadership of the nation is called upon to correct society's actions. There is a great pressure for immediate implementation of abatement.

7. *Stringent Target Abatement Goals Are Set:* With relatively little information available on causes, sources, abatement technology, or benefits and costs, but with a growing pressure for correction, standards are set.

8. *Reaction from Polluters:* Regulations are made in an atmosphere of emotional clamor and, in the absence of sufficient and pertinent facts, are apt to be restrictive enough to bring immediate reaction from polluters.

9. *Response to the Need for Abatement:* As more and better cause-and-effect data are accumulated there is a greater acceptance of abatement standards, but at a cost to the consumer in higher prices. Industry is forced into research in order to know as much about their pollution problem as does the abatement agency.

10. *Reviews and Second Thoughts:* As research and monitoring are improved, the quality issue gains a deeper perspective. Noticeable improvements will have been made in the gross and obvious contaminants; some operations will be closed down. Goals will be re-expressed in a more realistic way, taking into account the assimilative capacity of air and water, and the local variations of terrain and weather.

11. *Negotiations for Long-term Management:* As the climate for discussion becomes less emotional, less polarized, and based on greater knowledge, society begins to accept commonsense tradeoffs. Environmental quality values are compared with benefits of resource use in the standard of living. The data and mechanisms for cost effectiveness are improved to the point where complex ecosystems *can* be managed for optimum yield to civilization.

In the same document it is observed that both administrative and judicial bodies are being asked to act without being able to document the basis for their decisions. Some actions will be correct and others will turn out to be wrong. And finally, "A well-intentioned but poorly-informed society is haphazardly deploying a powerful, accelerating technology in a complex and somewhat fragile environment. The consequences are only vaguely discernible." Among its conclusions is this statement: "There are conflicts when the environmental quality is managed by different policies, originating in conservation, agriculture, aesthetics, recreation,

economic development, human health, and so forth. An *overall* policy for the environment must be established which integrates these purposes and objectives and which provides for choice when they are incompatible."

Sound information is certainly germane to any policy, whatever its derivation. The Report of the President's Science Advisory Committee, "Restoring the Quality of Our Environment" (Anonymous, 1965), included these basic principles:

"The public should come to recognize individual rights to quality . . ."

"All agencies . . . concerned with pollution should srengthen programs that lead to better public understanding . . ."

"In making decisions . . . information about effects and behavior of pollutants should be an essential consideration."

The web of life is a single system, but it is dealt with in segments, out of necessity. The bases for policy are therefore also numerous. Among the bases it is thought necessary (Anonymous 1968a) to include: (1) increased ecological understanding; plus (2) the analytical approach for coping with large complex systems. In the first case, ecological management requires a baseline of factual observations of the way things are in nature, such as the International Biological Program is hoped to produce. The second requirement calls for accurate mathematical models of the interrelations in the biosphere, which can be manipulated by a computer so that *many* variables may be studied. For example, sometime soon a model of the earth's meteorlogical system may be available. Then, various rates of fossil fuel combustion and the resulting carbon dioxide in the air could be simulated. Simultaneously, values for atmospheric reflectivity due to particular pollution could be introduced. The complex question of whether the earth might cool off or warm up could at least be examined before predictions of extinction were broadcast.

Surely a greatly accelerated search for knowledge of the environment is necessary and has been called for by various authorities (Anonymous, 1968a). Data must be organized and correctly interpreted. The physical, biological and social sciences must be deployed to obtain the knowledge. A research strategy must be devised to get the relevant facts as soon as possible. An organizational structure of public and private institutions must use the facts efficiently and objectively.

The Entomologist's Role In The Future

What, then, are the implications to the entomologist for the future? I have selected several concepts that appear worthy of consideration by entomologists within the context of pollution by pesticides.

About two years ago, our Research Subcommittee recognized the need for a broader basis on which to judge the benefits versus the risks of pesticide use and related aspects of pest control. We asked Dr. J. C. Headley to come before our subcommittee and provide details referred to in his book, *The Pesticide Problem: An Economic Approach to Public Policy* (Headley and Lewis, 1967). We felt then, as we do now, that the major advantage of an analysis of the costs and benefits to society of alternative actions affecting pest control is that such an analysis compels consideration in the decision-making process of the full range of available alternatives, including some which may not otherwise be recognized as alternatives. In all probability, no single course of action is sufficient in itself to yield the best possible outcome for society.

I will summarize this concept briefly:

Two basic types of costs must be considered in evaluating the benefits/cost ratio for pesticides. First are the obvious costs of the material itself, the use of

equipment with which it is applied, and the labor required to apply it. These are rather easily evaluated in dollar terms. In the case of agricultural production these costs are to be balanced against the increased value of the crop resulting from the degree of control achieved. If the returns are significantly better than $1 for each $1 expended for control, the expenditure is considered a good investment by the farmer. Headley conducted a study of this ratio a few years ago and concluded that the average farmer in his study received about $4 for each $1 invested in pest control. The conclusion appears to be warranted that the farmer would be justified in spending more for pest control than he did at that time.

Headley recognized that these figures represent only the direct costs and benefits. From the standpoint of the public interest, indirect costs and benefits must also be considered. These are much harder to evaluate in objective terms and to apply numerical values such as dollar equivalents. In fact, different segments of our society would evaluate them quite differently. Thus the costs in terms of actual or potential damage to fish or wildlife would be placed quite high by conservationists. Potential hazards to human health, particularly as they suggest the possibility of cancer or death, are frequently so emotionally charged that many people would evaluate these costs as approaching infinity, i.e., no benefit would justify them.

Headley has pointed out that there are various techniques by which dollar values *can* be assigned to such costs, though any one evaluation will not satisfy all interested persons. The value of lake trout killed by DDT can be measured in terms of cost of restocking the lake, or if this cannot be done because of persistent residues, then by the loss if net revenue to resort owners plus the cost to fishermen to go to a more distant lake. Headley points out that the cost of a human life is often evaluated by courts, e.g., in terms of expected life earnings. It may also be evaluated in terms of how much money a community is willing to spend in order to further reduce the number of traffic fatalities: records could provide a rather accurate estimate of such costs. Human lives might also be evaluated in terms of how much money society is willing to spend to further reduce deaths from malaria or some other preventable disease.

These indirect costs must be balanced against similar indirect benefits which are equally difficult but not impossible to evaluate in numerical terms. Such indirect benefits include a larger or higher quality food supply that may be evaluated in terms of the higher prices that higher quality goods bring on the market. They include freedom from annoying pests such as mosquitoes, roaches, and rats, improved recreational facilities, and reduction of pest-borne diseases.

In order to complete the economic story it is necessary to decide who is to pay for the indirect costs and how they are to be levied. There is an obvious limit to how much of such costs can be levied against the manufacturer, who must pass them on to his customer, at which point they are added to the direct costs. Insofar as Headley's first estimate of a $4 return for every $1 invested can be accepted, it would appear that the farmer can accept some of this added cost. It is doubtful that he will be willing to do so as long as he has alternatives to consider. This means that if society is to levy the increased cost against the manufacturer, alternative methods of control must be considered.

If the alternative method of control carries lower indirect costs — for instance, substituting a less persistent pesticide for a more persistent one — then it may be acceptable to force the manufacturer to absorb some of the costs or stop producing the more expensive pesticide.

Another possibility is that the alternative method of control may have lower indirect costs but may be so expensive to the user that he cannot afford to pay for it. As an extreme example, the alternative method of controlling the codling moth by releasing sterile codling moths has a much lower indirect cost than does the

current use of pesticides, but the cost of producing the sterile moths is now prohibitive to the apple grower. Therefore, in this example, society must find a way of paying the initial cost of such desirable alternatives, presumably as a direct federal subsidy.

Other methods of assessing the indirect costs of undesirable pesticides might include taxing the user directly and simultaneously subsidizing the user of more desirable alternative control methods. Similarly, much of the indirect cost of persistent pesticides arises because of the careless or excessive application by users who find it cheaper to overtreat than to employ better trained applicators and advisors. Insofar as this is true, some of the proceeds of the tax on the user could be rebated to those users who can prove that they are following good control practices.

Another important concept which embodies economic requirements is that of integrated control systems. Dr. Donald Chant is a foremost proponent of this approach.

Chant (1966) explained that this approach differs from being simply one more method in the deliberateness of the attempt to blend and harmonize the different techniques making up the integrated control system. Objectives are defined in terms of a permissible or tolerable damage level and construction of an integrated program that will result in this level. The program is based on pest management at levels below those of economic importance by harmonizing and applying two or more control techniques.

An example may serve to further define the integrated system of pest population control. At the peak of the spotted alfalfa aphid spread through 33 states, loss was at $42 million. Though a pesticides program was largely successful in control, 2 to 6 sprays were required each season at an average cost of $10 per acre. The first step toward an integrated control system was the development of several varieties of alfalfa that were partially resistant to the aphid. These were found to have greatest value against a background of natural mortality caused by parasites, predators and disease. As a result of this finding, parasites were imported from Europe and the Middle East, reared, and released. Also, a systemic pesticide was found that would further reduce the numbers of aphids but cause little harm to parasites and predators. A species of fungi was also discovered to play a part in the reduction of aphids. Losses today are far below those of yesterday and much less pesticide is required. Individually, these methods were unable to solve the problem; together and in proper combination, they provided an outstanding example of the value of this method.

Chant suggests three clearly defined primary research needs: research on the economics of crop production relative to pests and pest control and on economic injury levels relative to individual pest species; analysis of the dynamics of the pest populations relative to mortality factors already operating in the ecosystem; and study of the supplemental methods of control available for use in the particular ecosystem of interest to us to determine which are most suitable.

Of particular interest is what Chant refers to as the new breed of scientist required for research on pest management systems — one who is first and foremost a biologist in the broadest sense; one with a good background in traditional principles, but also fully familiar with behavior, toxicology, population ecology and genetics, resource management and the techniques on which it rests, systems analysis, economics, biomathematics and computer programming. Of course, the only practical way in which this array of talents can be brought to bear on the complex problems of pest control is by the cooperation of an interdisciplinary research team.

I would like to return to a point stressed by Chant. He calls the "principle of economic thresholds" the first and most important basic element in integrated

control systems and defines it as the level at which damage can no longer be tolerated and, hence, the level at or before which it is desirable to initiate deliberate control activities. Adherence to the principle of *not* spraying below an identified level has important implications to excess pesticides in the environment. This represents the "treat-when-necessary" philosophy. It is an unfortunate contrast that because of economics the investor in a crop can ill afford to risk his investment by haphazard pest control. As Smith (1968) has stated, the agriculture businessman must meet the exacting demands of the marketplace, and this makes near-perfect pest control the objective. The marketplace in turn caters to the demands of buyers, housewives in particular, whose aesthetic sense is offended by pests in the produce. Incorporated into laws are exacting market grades that the consumer expects. It is an escalating cycle, gone too far in some cases, such as standards to establish levels of contamination by insect fragments in processed fruits and vegetables. Should entomologists — perhaps those at universities and extension centers — make efforts to reverse these trends in the interest of an improved environment?

Along with the growing concern for pesticides as pollutants is a realization that most of the pesticide which is applied misses its intended target. The President's Science Advisory Committee (Anonymous, 1965) noted that methods and equipment presently used for large-scale applications of pesticides are relatively inefficient and unsophisticated. Under optimum conditions, they said 50 to 75% of the insecticide is useless for pest control and falls to the ground or drifts away to become an undesirable and unnecessary environmental contaminant. Pesticides with increased activity, better persistence, systemic and residual fumigant action have made it unnecessary to seek complete coverage. The report concludes that there is an urgent need for team research on the principles involved in pesticide application and on the design of better application equipment. The establishment at major agricultural experiment stations of research teams of physicists, engineers, chemists and biologists with the objective of exploring the field of pesticide application would yield valuable dividends in improving the efficiency of pest control and in decreasing the problems of environmental contamination by pesticides.

In thinking of ways to reduce the pesticide burden in the environment, our attention should be called to the desirability of maintaining diversity in the environment. According to Cole (1966), all communities harbor some "opportunistic species" — plants and animals that are normally inconspicuous but that quickly invade and occupy temporary habitats which appear after events such as fires, landslides, hurricanes, or clearing by man. Great reproductive potential, great powers of dispersal and generalized adaptability are the essential qualities for these species, and these traits have made them what man calls "pests". Modern farmers plant tremendous acreages of a single variety of crop plant in the belief that this practice increases efficiency. This, plus the modern trend toward clean cultivation, the elimination of hedgerows between fields and the like, reduces the diversity of species and assures that man will have to compete with opportunistic species for the harvest. By planting a *mixture* of varieties of grain that differ in the strains of rust to which they are susceptible, the oat field gains some of the properties that make for stability in the mixed forest — the fungus is deprived of the ability to sweep rapidly over the entire field by merely leaping from one plant to the next. Ecologically, Cole says, this is clearly a step in the right direction; he wonders if it would not be worthwhile to re-examine the whole question of agricultural efficiency from an ecological standpoint. Does the economy attained by harvesting huge continuous acreages really pay for the excess pesticides that might be eliminated by planting smaller fields or strips in such a way that quite different crops would be adjacent to each other?

Although it is generally accepted that pesticides represent minor pollutants in most media where they are found at the present, it is my opinion that, without increases in their residues, they may well be the focus of greater attention in the future. My rationale is this: within a few years major pollution problems will be gradually coming under control, decreasing to a lower order of importance. Then, relatively speaking, the ubiquitous, biologically-active pesticides will ascend the scale of importance, especially if continued research implicates them in the decline of endangered wildlife species. The degree of sensitivity that has been developed for the detection of pesticides is unique among the long list of environmental pollutants. This ability to detect *traces* of pesticides will serve to enhance the focus of attention on this particular group of pollutants.

Recently received was an "Interim Report for the International Council of Scientific Unions, Special Committee for the International Biological Program on the Need for A Global Network for Environmental Monitoring" (Blair, 1969). At their special meeting in Johannesburg, South Africa, July 1969, they enumerated some of the reasons for monitoring biological quality through a global network, as follows:

1. In an ecosystem, the biological organisms integrate all environmental effects and hence it reflects the *total* environment.

2. Biological monitoring is necessary to reveal the trends in the system and the rate of change in our environment.

3. Biological monitoring is necessary to show the pathways and points of accumulation of pesticides and other pollutants in ecological systems.

4. In the monitoring of biological systems we are actually monitoring the economic resources of the world.

I believe that this effort deserves our support. The Federal Committee on Pest Control is working hard to encourage monitoring of pesticides and the dissemination of monitoring data. In this regard, we have sponsored a National Pesticide Monitoring Program and a Pesticide Monitoring Journal. We feel that these efforts will make a substantial contribution to the accumulation of needed information, referred to earlier. This will help to provide the scientist-administrators on our Committee, and those elsewhere, with a better basis for making sound, unemotional decisions on risks versus benefits.

A number of professional societies and scientific institutions have recently become involved in environmental quality (Anonymous, 1968a). For example: *The Ecological Society of America* has begun a far-reaching program to strengthen the profession and to take part in public affairs, particularly to bring ecological implications to the attention of policymakers. *The American Chemical Society* has added a Subcommittee on Environmental Improvement to its Committee on Chemistry and Public Affairs. Their first goal is an objective account of what is known chemically about environmental quality matters. The *National Academy of Sciences* and the *National Academy of Engineering* have established an Environmental Studies Board. One of their first endeavors is an independent evaluation of the effects on human health and well-being of the contaminants of the environment, as opposed to the feasibility and cost of achieving various levels of contaminant reduction. And the *American Association for the Advancement of Science* has formed a Committee on Environmental Alteration in order to facilitate the development of disciplined means of collecting information, planning, studying and controlling large-scale interventions into natural systems.

In conclusion, it has been said that man's intentions of using nature to further his own well-being *are* correct. Even the best intentions may bring environmental degradation if they are clumsily executed on the basis of insufficient information. The lesson today is that man's powers rival those of the biosphere. In

certain ways, the environment may have Achilles' heels, attacks on which can lead to unwanted changes very rapidly. An overpopulated and underfed world leaves very little room for mistakes. The more that is learned about ecology today, the clearer it becomes that the management of the environment is a crucial task, rivaling the search for peace in the world.

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III. SUBMITTED PAPERS

THE DISTRIBUTION AND SURVIVAL OF OVERWINTERING CODLING MOTH LARVAE IN SOUTHERN ONTARIO*

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Abstract

The relative numbers of overwintering codling moths in unsprayed orchards were measured in six regions in southern Ontario. Larval densities varied considerably but were always highest on the first two feet of trunk above ground level irrespective of geographical location, apple cultivar, or full trunk height. The number of larvae per tree trunk was significantly correlated with trunk area, but not with the amount of bark present. Bird predation was the most important factor affecting larval survival in all orchards sampled.

Introduction

One of the major factors affecting the economic production of apples in Ontario is fruit loss due to insect infestation. Large quantities of insecticides must be applied during the growing season in order to control these pests, with consequent adverse effects on the orchard fauna, as well as contamination of the environment. In view of the latter effects, studies on the bionomics of the codling moth, *Carpocapsa pomonella* (L.), one of the major apple pests, are being undertaken with a view to developing integrated control procedures which would make more efficient use of natural control factors. Although several studies on the biology and behavior of the moth in Ontario have been made (cf. Putman, 1963), the last extensive field study was reported on by Garlick in 1948; while Boyce (1941, 1943, 1948) studied its known parasites and predators.

Accordingly, a survey was initiated in the spring of 1968 to determine the relative numbers of codling moth present in unsprayed apple orchards in southern Ontario, and to assess the relative importance of biotic and abiotic factors in regulating moth density and survival.

Sample Orchards and Methods

1. *Orchards:* Codling moth populations were sampled in 15 unsprayed orchards in six regions in southern Ontario in 1968 and 1969. The location of the orchards together with their acreage and the main cultivars grown were as follows: (1) in the Niagara peninsula at Vinemount (8 acres, McIntosh), Vineland (3 acres, Northern Spy, Rhode Island Greening), Fonthill (1.5 acres, Northern Spy, Delicious, McIntosh); (II) in the Georgian Bay area at Clarksburg (2 acres, Northern Spy) and Meaford (3 acres, Northern Spy, McIntosh, King); (III) in the eastern

*Contribution No. 188

region at Brighton (4 acres, Northern Spy, Snow, Rhode Island Greening), Trenton (7 acres, McIntosh, Spy, Melba) and Rednersville (6 acres, Snow); (IV) in the western region at Guelph (No. 1, 5 acres, Northern Spy; and No. 2, 3 acres, McIntosh, Northern Spy); (V) in the southern region at Vittoria (No. 1, 40 acres, McIntosh, Northern Spy, Snow, Rhode Island Greening, Wealthy, Baldwin; No. 2, 5 acres, Northern Spy) and Lynn Valley (3 acres, Snow); and (VI) in the southwest at Reece's Corner (8 acres, McIntosh, Red Delicious, King, Jonathan), Essex (1.5 acres, Northern Spy) and Cedar Springs (4 acres, McIntosh, Northern Spy).

Pesticides had not been applied to the study orchards for a period of at least two years, and trees selected for sampling varied between 25 and 40 years of age.

2. *Sampling Technique:* The bark from individual tree trunks and branches was scraped off at 1- and 2-foot intervals respectively onto a piece of muslin tacked around the base of the tree. The bark scales from each sample unit were collected separately in plastic bags and subsequently examined in the laboratory for the presence of codling moth cocoons. Old cocoons spun prior to the fall of 1967 were not included in the data recorded.

Larval Density and Distribution

1. *Geographical:* The data obtained on the relative numbers of overwintering codling moth larvae are summarized in Tables I and II. In all areas in which the same orchards were sampled in both years, fewer larvae were generally observed in 1969, particularly at Brighton and Guelph where the average number of larvae per trunk foot was 4.0 and 3.7 in 1968, and 2.1 and 2.3 in 1969 respectively. In orchards sampled only in 1969 larval densities also tended to be generally lower than those observed in the same area in 1968, with the exception of one orchard in the Georgian Bay area where an increase to 4.1 from 1.0 larva per trunk foot was observed. There was also considerable variation in the numbers of larvae observed between orchards separated by only a few miles in the same geographical area as shown at Brighton and Trenton and at Vittoria (Table 1), and at Vittoria and Vineland, Jordan and Fonthill (Table II).

In the spring of 1968 the largest numbers of larvae were recorded at Vinemount (4.5 per trunk foot), Brighton (4.0 per trunk foot), and Guelph (3.7 per trunk foot), and the lowest at Reece's Corner (0.7 per trunk foot), Rednersville (0.8 per trunk foot), and Clarksburg (1.0 per trunk foot). In 1969 larval densities were greatest at Meaford (4.1 per trunk foot) and lowest at Rednersville, Vittoria and Reece's Corner (0.2, 0.4 and 0.5 per trunk foot respectively).

Larval densities in the fall (Table II) did not vary significantly between orchards except for those observed at Clarksburg in 1968 and at Jordan in 1968 and 1969.

Larger numbers of insects spun cocoons on trees in the northern and western aspects of the orchards sampled (Table III). As the prevailing winds were generally from the southwest, the distribution observed probably reflects adult selection of the most protected parts of the orchard for egg laying.

2. *Cultivars:* There was little difference between the numbers of larvae that spun cocoons on five apple cultivars in the fall (Table IV). This indicated that suitable cocooning sites were generally available to the larvae irrespective of the cultivar selected. A smaller proportion of the larvae, however, appeared to survive the winter on the trunks of Spy and Delicious trees (Table V). The smaller amount of bark scales on the trunks of these cultivars (Table VI), probably afforded the insects less protection from parasites and predators.

TABLE I. Densities of overwintering codling moth larvae in southern Ontario in spring in 1968 and 1969[1]

Orchard location		No. trees sampled		No. trunk foot samples examined		No. codling moth recovered				No. codling moth per tree				No. codling moth/ trunk foot			
						Total		Living		Total		Living		Total		Living	
County	Nearest town																
Grey	Clarksburg	12		42		42		10		3.5		0.8		1.0		0.2	
	Meaford		(7)[2]		(29)		(118)		(39)		(16.9)		(5.6)		(4.1)		(1.3)
Prince Edward	Rednersville	7	(2)	17	(10)	13	(2)	0	(0)	1.9	(1.0)	0	(0)	0.8	(0.2)	0	(0)
Northumberland	Brighton	8	(5)	18	(17)	72	(35)	16	(3)	9.0	(7.0)	2.0	(.6)	4.0	(2.1)	0.9	(0.2)
	Trenton		(2)		(5)		(4)		(0)		(2.0)		(0)		(0.8)		(0)
Essex	Essex		(4)		(17)		(34)		(2)		(9.3)		(0.5)		(2.0)		(.1)
Lambton	Reece's Corner	7	(4)	18	(13)	12	(7)	2	(0)	1.7	(1.8)	0.3	(0)	0.7	(0.5)	0.1	(0)
Kent	Cedar Springs	5		12		22		4		4.4		0.8		1.9		0.3	
Norfolk	Vittoria	29		67		211		46		7.3		1.6		3.2		0.7	
Norfolk	Vittoria		(8)		(48)		(20)		(1)		(2.5)		(0.1)		(0.4)		(0.2)
Wellington	Guelph	10	(4)	21	(14)	77	(32)	17	(5)	7.7	(8.0)	1.7	(1.3)	3.7	(2.3)	0.8	(0.4)
Wentworth	Vinemount	18		70		316		38		17.6		2.1		4.5		0.5	
Lincoln	Vineland		(8)		(41)		(42)		(8)		(5.2)		(1.0)		(1.0)		(0.2)
Welland	Fonthill		(4)		(15)		(38)		(6)		(9.5)		(1.5)		(2.5)		(0.4)
	Totals	97	(48)	286	(195)	773	(338)	152	(64)								

[1]Samples taken between April 25 and June 20 in 1968 and May 1 and June 12 in 1969
[2]1969 data in parentheses

TABLE II. Densities of overwintering codling moth larvae in southern Ontario in the fall in 1968 and 1969[1]

Orchard location		No. trees sampled		No. trunk foot samples examined		No. codling moth recovered				No. codling moth per tree				No. codling moth/ trunk foot			
						Total		Living		Total		Living		Total		Living	
County	Nearest town																
Grey	Clarksburg	2		7		5		5		2.5		2.5		0.7		0.7	
	Meaford		8[2]		(48)		(87)		(50)		(10.9)		(6.3)		(1.8)		(1.0)
Northumberland	Brighton	2	(4)	5	(20)	12	(50)	11	(35)	6.0	(12.5)	5.5	(8.8)	2.4	(2.5)	2.2	(1.8)
Lambton	Reece's Corner	3		7		30		12		10.0		4.0		4.3		1.7	
Norfolk	Lynn Valley		(2)		(9)		(15)		(9)		(7.5)		(4.5)		(1.7)		(1.0)
	Vittoria	7		24		126		57		18.0		8.1		5.3		2.4	
	Vittoria		(2)		(12)		(25)		(17)		(12.5)		(8.5)		(2.1)		(1.4)
Wellington	Guelph	4	(3)	14	(18)	67	(45)	31	(18)	16.8	(15.0)	7.8	(6.0)	4.8	(2.5)	2.2	(1.0)
Lincoln	Vineland	8	(3)	27	(24)	108	(25)	86	(16)	13.5	(8.3)	10.8	(5.3)	4.0	(1.0)	3.2	(0.7)
Lincoln	Jordan[3]	4	(2)	9	(6)	112	(87)	46	(56)	28.0	(43.5)	11.5	(28.0)	12.4	(14.5)	5.1	(9.3)
Welland	Fonthill		(2)		(9)		(32)		(11)		(16.0)		(5.5)		(3.6)		(1.2)
	Totals	30	(26)	89	(146)	460	(366)	248	(212)								

[1]Samples taken between Sept 17 and Oct 21 1968 and Sept 3 and Oct 14 in 1969
[2]1969 data in parentheses
[3]A small planting of 20 trees

TABLE III. Relative densities of overwintering codling moth larvae in the cardinal aspects of the orchards sampled

Observations	Cardinal aspect				
	North	South	East	West	Totals
Total No. codling moth larvae recovered	403(125)[1]	321(77)	274(72)	441(126)	1439(400)
Total No. trees sampled	40	42	37	45	164
No. trunk (foot) samples examined	103	135	102	133	473
Average No. codling moth larvae per (1) tree	10.0(3.1)	7.6(1.8)	7.4(1.9)	9.8(2.8)	
(2) trunk foot	3.9	2.4	2.7	3.3	

[1]Numbers of living insects in parentheses

TABLE IV. Densities of codling moth larvae in the fall on the trunks of five apple cultivars

Observations	Apple cultivar					
	Spy	McIntosh	Delicious	Rhode Island Greening	Snow	Totals
Total No. trees sampled	19	5	6	9	7	46
No. trunk (foot) samples examined	80	23	24	42	28	197
Total No. codling moth larvae recovered	273(164)[1]	86(36)	78(50)	148(76)	79(41)	664(367)
Average No. codling moth larvae per (1) tree	14.4(8.6)	17.2(7.2)	13.0(8.3)	16.4(10.7)	11.3(5.9)	
(2) foot of trunk	3.4(2.1)	3.7(1.6)	3.3(2.1)	3.5(2.3)	2.8(1.5)	

[1]Numbers of living insects in parentheses

TABLE V. Densities of codling moth larvae in the spring on the trunks of five apple cultivars

Observations	Apple cultivar					
	Spy	McIntosh	Delicious	Rhode Island Greening	Snow	Totals
Total No. trees sampled	47	29	11	10	11	108
No. trunk (foot) samples examined	166	78	29	34	31	338
Total No. codling moth larvae recovered	228(62)[1]	315(46)	55(7)	99(23)	137(21)	834(155)
Average No. codling moth larvae per (1) tree	4.9(1.3)	10.9(1.6)	5.0(0.7)	9.9(2.3)	12.5(1.9)	
(2) foot of trunk	1.4(0.3)	4.0(0.6)	1.9(0.2)	2.9(0.7)	4.4(0.7)	

[1]Numbers of living insects in parentheses

TABLE VI. Average weight (gm) of the bark removed per foot from the trunks of five apple cultivars

Cultivar	No. trees sampled	No. foot samples	Average bark weight (gm)[1]
Delicious	10	26	138.4
Spy	12	33	153.2
McIntosh	12	31	224.3
Snow	5	15	228.7
Rhode Island Greening	5	12	239.1

[1]Bark removed to a height of 3 feet

3. *Individual Trees:* The largest number of overwintering larvae was observed (Table VII) on the first two feet of tree trunk above ground level, irrespective of geographical location, tree position in the orchard, full trunk height, or apple cultivar. Further, the number of larvae per tree trunk foot was highly correlated with trunk area (Table VIII), but not with the quantity of bark present on individual foot sections.

TABLE VII. Distribution of overwintering codling moth larvae on the trunks and branches of apple trees

Area	Total No. foot samples	Distance (feet) above ground level (trunk) and from union with stem outwards (branches)[1,2]					
		1	2	3	4	5	6
Trunk	414	2.6	2.8	2.5	1.1	0.9	0.4
Branches	105		0.6		0.3		0.3

[1]Based on observations made in the spring on 146 trees
[2]Bark scales removed from 2 feet of branch per sample

TABLE VIII. Correlation between number of insects recovered per trunk foot and bark weight and trunk area[1,2]

Observations	Trunk height above ground level (feet)					
	1	2	3	4	5	6
Average No. larvae recovered	5.5	4.4	2.7	1.3	0.9	0.5
Average bark weight (gm)	180	209	177	109	108	105
Average trunk area (square feet)	3.7	3.6	3.5	3.1	2.8	2.6

[1]Based on observations on 49 trees sampled in the fall
[2]High correlation between the No. of larvae recovered and trunk area ($r = 0.93$ significant at 1% level)

Factors Affecting Mortality

Predation was the most important factor affecting the mortality of hibernating larvae (Table IX). Bird predation which accounted for more than 90% of that observed, was greatest in orchards at Vittoria, Brighton and in the Niagara peninsula and lowest in those at Reece's Corner, Cedar Springs, and in the Georgian Bay area.

TABLE IX. Factors affecting the mortality of overwintering codling moth larvae in southern Ontario

Sampling dates	Orchard location	% mortality due to			
		Disease	Parasites	Predators	Frost
	Clarksburg	34.4	9.4	53.1	3.1
A. Spring	Meaford	(7.9)[1]	(18.2)	(74.0)	(0)
1968 (25/4-20/6)	Vittoria	7.9(3.0)	0.6(0)	90.3(97.0)	1.2(0)
1969 (1/5-12/6)	Guelph	23.3(18.5)	8.3(7.4)	66.7(74.1)	1.7(0)
	Brighton	8.9(7.5)	5.4(5.0)	85.7(85.0)	0(2.5)
	Rednersville	100.0[2]	0	0	0
	Cedar Springs	66.7	0	33.3	
	Reece's Corner	33.3(12.9)	4.2(7.1)	62.5(82.0)	0(0)
	Vinemount	3.2	3.6	92.8	0.4
	Vineland	(19.5)	(2.7)	(77.8)	(0)
	Fonthill	(12.1)	(0)	(84.8)	(3.1)
B. Fall	Clarksburg	0	100.0[3]	0	
1968 (17/9-21/10)	Meaford	(2.7)	(37.8)	(59.5)	
1969 (3/9-14/10)	Vittoria	14.6(21.4)	31.9(14.3)	53.6(64.3)	
	Guelph	16.9(33.3)	38.9(7.4)	44.4(59.3)	
	Brighton	(6.7)	(80.0)	(13.3)	
	Reece's Corner	55.6	22.2	22.2	
	Vineland	12.0(0)	24.0(11.1)	64.0(88.9)	
	Jordan	65.1(13.3)	10.7(64.1)	24.2(22.6)	
	Fonthill	(23.8)	(14.3)	(61.9)	

[1]1969 data in parentheses
[2]Only 3 specimens collected
[3]Only 1 specimen collected

The incidence of disease varied greatly between and within the sample orchards in both 1968 and 1969. Although mortality due to disease was occasionally high in some areas, (Clarksburg 34.4%, Cedar Springs 65.1%, Reece's Corner 55.6% and Jordan 65.1%), no consistent trends were observed.

In the fall, the level of parasitism was 31.9% at Vittoria and 38.9% at Guelph in 1968, and 37.8% at Meaford, 64.1% at Jordan, and 80% at Brighton in 1969. In all other orchards in both years mortality due to parasitism was low.

In all areas sampled larval mortality resulting from low winter temperatures was negligible.

Summary

The relative numbers of overwintering codling moths in unsprayed orchards were measured in six regions in southern Ontario. Larval densities varied considerably but were always highest on the first two feet of trunk above ground level irrespective of geographical location, apple cultivar or full trunk height. The number of larvae per tree trunk was significantly correlated with trunk area, but not with the amount of bark present. Bird predation was the most important factor affecting larval survival in all orchards sampled.

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CERTAIN INTRINSIC FACTORS INFLUENCING THE POSTEMBRYONIC DEVELOPMENT OF THE PALPAL ORGANS IN THE WOLF-SPIDER *LYCOSA CHAPERI* S.

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Abstract

The development of the intromittent palpal organs in *Lycosa chaperi* has an apparent qualitative relationship with the endocrine secretions in the body. Three types of neuro-secretory cells have been observed to occur in the cephalothoracic nerve mass of the spider where the exact location of the cells has been studied and cell counts made in the pedipalpal ganglia. In addition to the neurosecretory cells two pairs of endocrine glands, called the Schneider's organs which are rich in neurosecretory material, also occur as components of the spider's stomodaeal nervous system. The activity of the neurosecretory system seems to parallel closely the growth phases of the palpal organs, indicating a possible hormonal role in the development of the male sex organs.

The palpal organs do not develop in the tibial joint of the pedipalpi if the tarsi are extirpated. The seat of the predetermined genetic material responsible for the development of the palpal organs lies only in the apical, tarsal epidermal tissue which is activated by the humoral factor.

The paired, intromittent copulatory organs of male spiders, known as the palpal organs, are located within the tarsi of their gnathal appendages, the pedipalpi. The ontogenetic postembryonic development of the palpal organs has been studied by various workers, notably Barrows (1925), Harm (1934) and Bhatnagar and Rempel (1962). Recently, Bhatnagar (1965) suggested that the development of the palpal organs in *Lycosa chaperi* was under the control of hormonal secretions in the body. In *Lycosa,* as in other spiders, the apical tarsal tissue in the pedipalp secretes a stout cuticular pretarsal claw in the earlier instars of the spider's life cycle. This tissue later undergoes hypertrophy and grows into the palpal organ in the final three instars. The principal intrinsic factor that influences the development of this organ seems to emanate from a sudden flux in the neurosecretory activity of the spider's neuroendocrine complex, triggering the morphogenetic and physiological changes in the tarsal tissue.

The neurosecretory cells in *L. chaperi* are not confined to the brain alone but are distributed along the cortex of the entire cephalothoracic, ganglionic nerve mass (Figures 1 and 2). The neurosecretory cells (NS.C) were observed to occur in an active secretory phase in the eighth and the ninth instars male spiderlings, paralleling the developmental stages of the palpal organs. Three secretory types designated as A-, B-, and C-types of cells have been located in the cortical, cellular region along the boundaries of the ganglia of the cephalothoracic nerve mass. The three morphological types were distinguished on the basis of their shape, size and the staining reaction of their secretory droplets. The staining techniques employed for this study were Bergmann's chrome-alum hematoxylin-phloxin and Gomori's paraldehyde fuchsin technique. The A-type cells are large, pear-shaped, and their cytoplasm is rich in huge secretory droplets. The B-types are smaller and round and their cytoplasm contains numerous minute secretory droplets. The C-cells are also small and round, with only a few, sparse, secretory granules. It was observed that there was a close relationship between the activity of the neurosecretory cells and the developmental stages of the palpal organs (Figure 3). The number of the three secretory types counted in the pedipalpal lobe of the cephalothoracic nerve mass from the seventh to the tenth (adult) instars indicated a distinctly increased neurosecretory activity during the eighth and the ninth instars when the tarsal tissue is growing into the palpal organ.

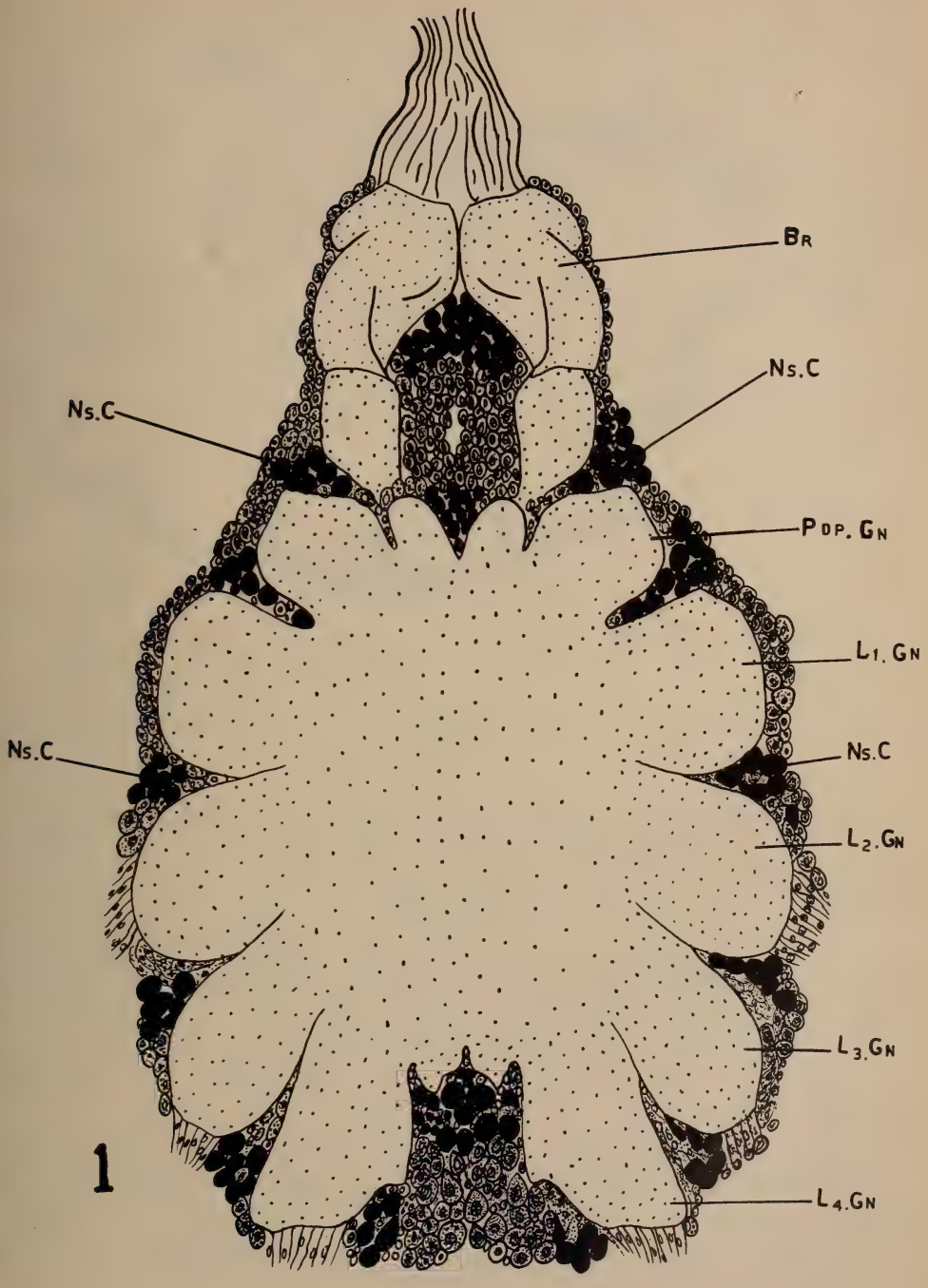

FIGURE 1. A horizontal section of the cephalothoracic nerve mass of *L. chaperi* showing the neurosecretory areas. (BR — brain, C.B. — central body, L1-L4 — leg ganglia. NS.C — neurosecretory cells, PDP.GN — pedipalpal ganglion, S.01, S.02 — Schneider's organs.)

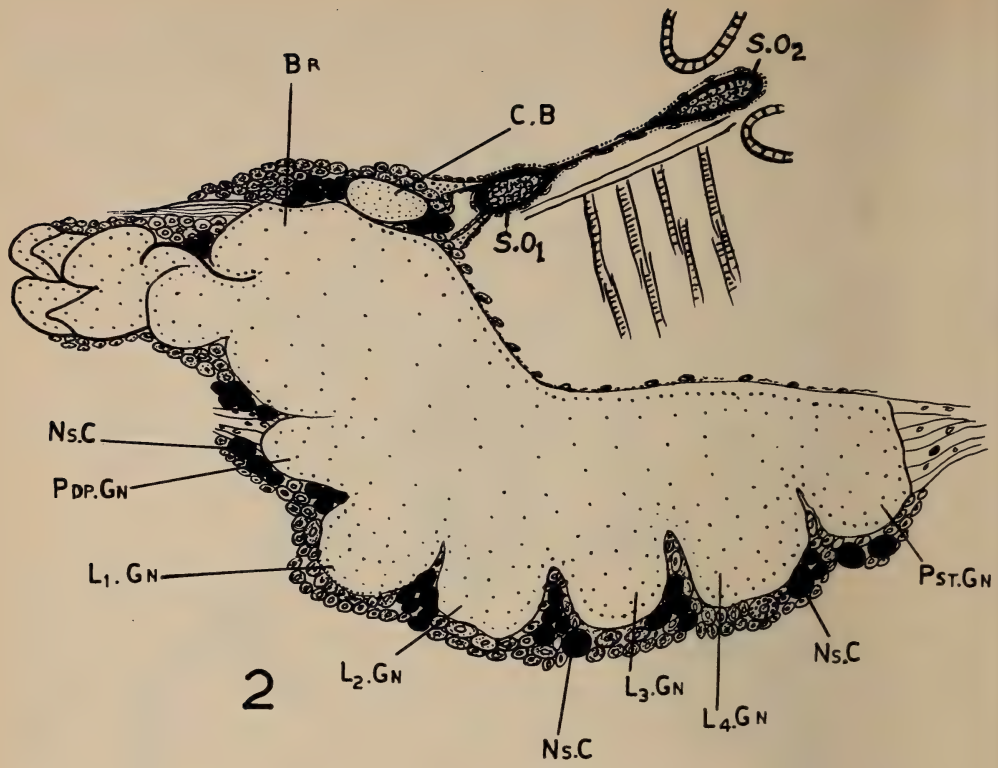

FIGURE 2. A sagittal section of the cephalothoracic nerve mass showing the neurosecretory areas.

In addition to the neurosecretory cells, two pairs of ganglionic bodies, known as Schneider's organs also occur in *L. chaperi* associated with the stomodaeal nervous system of the spider (Figure 2). Morphological aspects of the neuroendocrine system have been studied earlier in some other spiders by Legendre (1953, 1956 and 1958) and Kühne (1957 and 1959). The Schneider's organs of spiders are probably homologous with the corpora allata and cardiaca of insects. In *L. chaperi* these organs were observed to be rich in neurosecretory material. However, the function of these organs is as yet unknown; and, whether or not they have any role in the processes of growth and metamorphosis in spiders as the corpora allata and cardiaca have in insects is an open field of investigation.

The development of the palpal organs in spiders provides a remarkable illustration of gene-hormone interaction and further studies in this area can possibly lead to a better understanding of the manner in which hormones alter growth patterns in animals. Extirpation of the tarsal joint from the pedipalpi of the seventh instar spiderlings of *Lycosa* did not result in any appreciable cellular activity in the epidermal tissue of the preceding tibial joint. The seat of the predetermined genetic material responsible for the development of the palpal organ, therefore, lies only at the apex of the tarsal epidermis which is activitated by the humoral factor, after the seventh molt.

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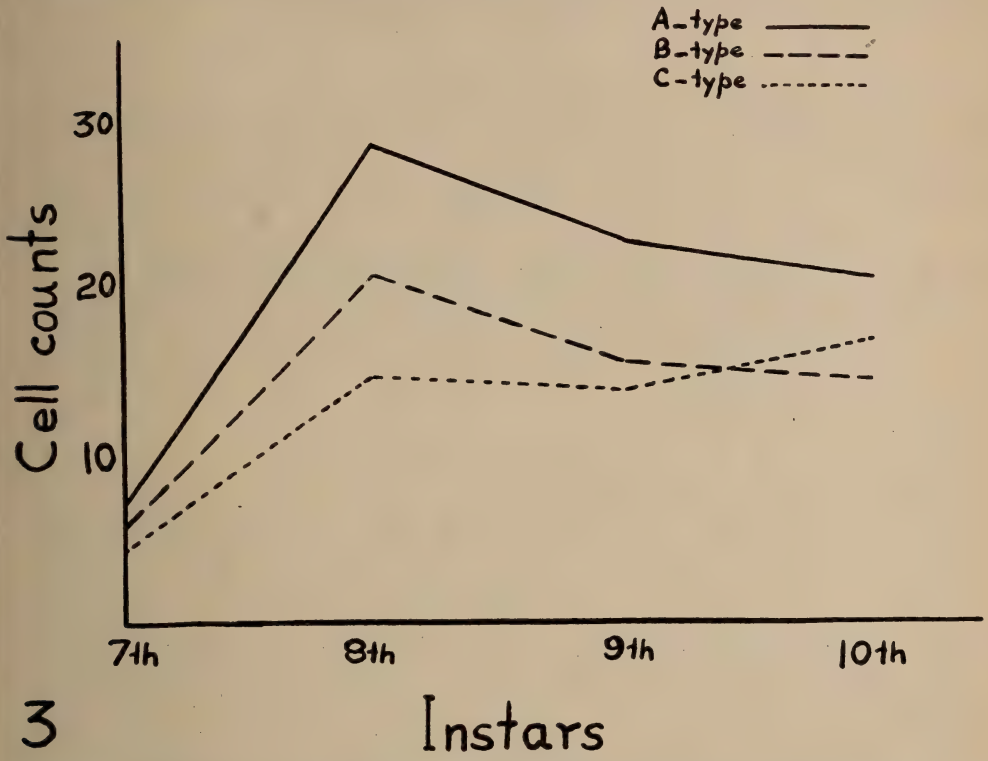

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FIGURE 3. Numbers of neurosecretory cells of A-,B- and C-types in the pedipalpal ganglia of seventh to tenth (adult) instars. Each point on the graph is a mean of counts of ten ganglia.

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IMMATURE STAGES OF FIVE DIVING BEETLES (COLEOPTERA: DYTISCIDAE), NOTES ON THEIR HABITS AND LIFE HISTORY, AND A KEY TO AQUATIC BEETLES OF VERNAL WOODLAND POOLS IN SOUTHERN ONTARIO

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Abstract

Among the aquatic beetles that prey on larvae and pupae of mosquitoes in temporary woodland pools in southern Ontario, five species of dytiscids were found to complete their development in this habitat. Most of the immature stages of these are described in detail, and a diagnostic key based on characters of the first- and third-instar larvae is provided. The habits and life history of each species are discussed. The extensive fauna of aquatic beetles in the vernal pool habitat is indicated by a key for separating the adults of 44 species, of which 34 are dytiscids.

Introduction

During ecological studies of mosquitoes in Ontario many water beetles were found to prey on aedine larvae and pupae in vernal pools (Baldwin, James and Welch, 1955; James, 1961). Most of these develop in other habitats and invade vernal pools as adults. However, five species of Dytiscidae were found to complete their development *in situ,* and thus, more than the other species, are closely associated with the mosquito fauna of such pools. These dytiscids are: *Agabus erichsoni* G. and H., *Rhantus binotatus* (Harris), *Colymbetes sculptilis* Harris, *Dytiscus fasciventris* Say, and *Acilius semisulcatus* Aubé.

Their eggs, larvae, and pupae could not be identified satisfactorily as descriptions were either lacking, fragmentary, or inadequate. Accordingly, the life histories were investigated in detail and the results constitute the main body of this contribution. Also, a key for identification of adults treats the 44 species of aquatic beetles, 34 of which are dytiscids, found in the vernal pool habitat. Many of these prey on mosquito larvae to some degree.

Good descriptions of dytiscid larvae and pupae were published by Wilson (1923), but the species studied by him were mainly those from open, more or less permanent fishponds whose insect fauna differed considerably from that of temporary pools. The descriptions of the immature stages of aquatic beetles provided here fill gaps in existing knowledge of the fauna of temporary woodland pools and should be useful to students of that habitat and particularly for studies of the ecological relationships of developing snow-melt mosquitoes.

Materials and Methods

Specimens for morphological study and illustration were collected over a period of several years from woodland pools in Sine's swamp and similar pools at the Institute field station, Chatterton (44°10'N., 77°23'W.) within 10 miles of Belleville. In 1963 additional specimens were collected in a tamarack swamp one mile north of Cordova Mines (44°32'N., 77°47'W.).

Eggs, excepting those present in soil samples or deposited in sedges, were obtained from females collected in April and May, and were incubated in aerated pond water at 20°C. The larvae of each of the three instars were reared individually in small Stender dishes and half-pint Mason jars and given *Daphnia* and

larvae of *Aedes aegypti* L. as food. Larvae of *Agabus erichsoni,* however, were given early-stage larvae of *Aedes stimulans* (Walk.) obtained by flooding soil samples; some of these aedines were reared to the fourth instar for identification. When third-stage predator larvae no longer fed they were transferred to moist soil in a small Stender dish.

Reared larvae were measured under a binocular microscope shortly after hatching and after each ecdysis. Other larvae were collected weekly in the pools, from mid-March to the end of July in order to follow development. Pupae in the soil around pool margins were exposed with little injury by uncovering them with a blunt-toothed hand cultivator; each was identified from the remains of the last larval skin found in the pupal cell.

Eggs and first-instar larvae were either coddled by immersion in water at 60°C for 5 minutes or fixed and stored in 80% ethyl alcohol. Small larvae and structures of larger larvae were left in 10% K OH solution for several hours, washed in distilled water, and mounted on slides in de Faure's medium (Beirne, 1955).

The length of the larva was measured dorsally, from the front of the clypeus to the tips of the cerci, not including terminal setae. The head width was taken at the widest point, usually near the ocelli; head length was the distance between the front of the clypeus and the posterior margin of the neck. Measurements of 10 or more specimens were expressed by the mean and standard deviation; for less than 10, by the mean and range (in parenthesis).

Key to Larvae

The species treated in the key below are characterized as dytiscids by (1) the campodeiform larva, consisting of a sclerotized head, three thoracic and eight visible abdominal segments; (2) a double gular suture; (3) a pair of longitudinal tracheae opening through caudal spiracles, and the presence of non-functional lateral spiracles in the third instar except during moulting or when out of water (Leech and Chandler, 1956); and (4) by five-segmented legs for walking or swimming.

1. Maxillary stipes broad, sub-oval (Figure 70), with 1 or 2 inner marginal hooks 2

   Maxillary stipes long and slender (Figures 50 and 56), with no inner marginal hooks ..... *Dytiscus fasciventris* Say

2. Abdominal segments 7 and/or 8 (first instar) with a lateral fringe of long swimming hairs (Figure 70); ligula present (Figure 75) ..... *Acilius semisulcatus* Aubé

   Abdominal segments 7 and/or 8 (first instar) without a lateral fringe of long swimming hairs; ligula absent 3

3. Fourth segment of antenna less than two-thirds as long as the third (Figure 2); cercus of first- and third-instar larva with 3 short setae near the base and 4 terminal setae (Figure 1); no secondary hairs ..... *Agabus erichsoni* G. and H.

   Fourth segment of antenna more than two-thirds as long as the third (Figure 48); cercus of first-instar larva with 3 long terminal setae (Figure 35); cercus of third-instar larva with numerous secondary hairs (Figure 43) 4

4. Cuticle of antenna rugose (Figure 18); cercus of first-instar larva with primary lateral setae arranged in pairs (Figure 22); average head width 0.70 mm; cercus of third-instar larva fringed mainly with lateral secondary hairs (Figure 33) ..... *Rhantus binotatus* (Harr.)

Cuticle of antenna smooth; cercus of first-instar larva with primary lateral setae well separated, not in pairs (Figure 35); average head width of first-instar larva 1.10 mm; cercus of third-instar larva fringed with secondary hairs on all sides (Figure 43) ..... *Colymbetes sculptilis* Harr.

Descriptions of Larvae

Agabus erichsoni Gemminger and Harold, 1868

Egg (Figures 5, 78)

Short oval, slightly broader toward anterior end. Chorion pale cream at first, becoming light brown and parchment-like with age; surface minutely sculptured. Mean length (8) 1.69 mm (1.59 — 1.81); diameter 1.12 mm (1.00 — 1.17). Nine eggs deposited on moss in submerged field cages averaged 1.76 mm (1.71 — 1.91) in length and 1.13 mm (1.01 — 1.18) in diameter.

First Instar (Figures 1 to 4, and 6 to 8)

Head subquadrate (Figure 1). Fronto-clypeal plate (Balfour-Browne, 1940) semi-triangular, rounded; epicranial suture half as long as head; frontal tubercle well developed, acicular. Ocular area with three pairs of ocelli: dorsal pair close together, lateral pairs well separated. Front margin of clypeus (Figure 8) slightly arcuate, with a row of about 22 club-shaped setae. Antenna (Figure 2) four-segmented, as long as head; segment III longer than II, twice as long as IV. Mandible (Figure 7) sharply falcate, twice as long as wide. Maxilla (Figure 6) with a short cardo, broad stipes, three-segmented palp, and one-jointed galea. Labium (Figure 3) with a sub-rectangular base half as long as wide; segment II of palp longer than I; mentum ventrally with a long seta near the base of the palp and 7 or 8 short setae on each side; ligula absent.

Abdomen tapering gradually from base, membranous beneath excepting last segment which is completely sclerotized. Cercus (Figure 1) terminating in a short spine and four setae that are four-fifths as long as the cercus. A single pair of spiracles occur dorsally on the eighth abdominal segment. Coxa of front leg (Figure 4) 2½ times as long as trochanter; tibia and tarsus sub-equal; natatory hairs absent.

Mean length of larva shortly after eclosion 6.47 mm (4.80 — 7.42). Head width 0.99 mm (0.95 — 1.06); head length 1.06 mm (0.93 — 1.17).

Length of field-collected larvae 7.32±0.45 mm; head width 1.11±0.25 mm; head length 1.28±0.21 mm.

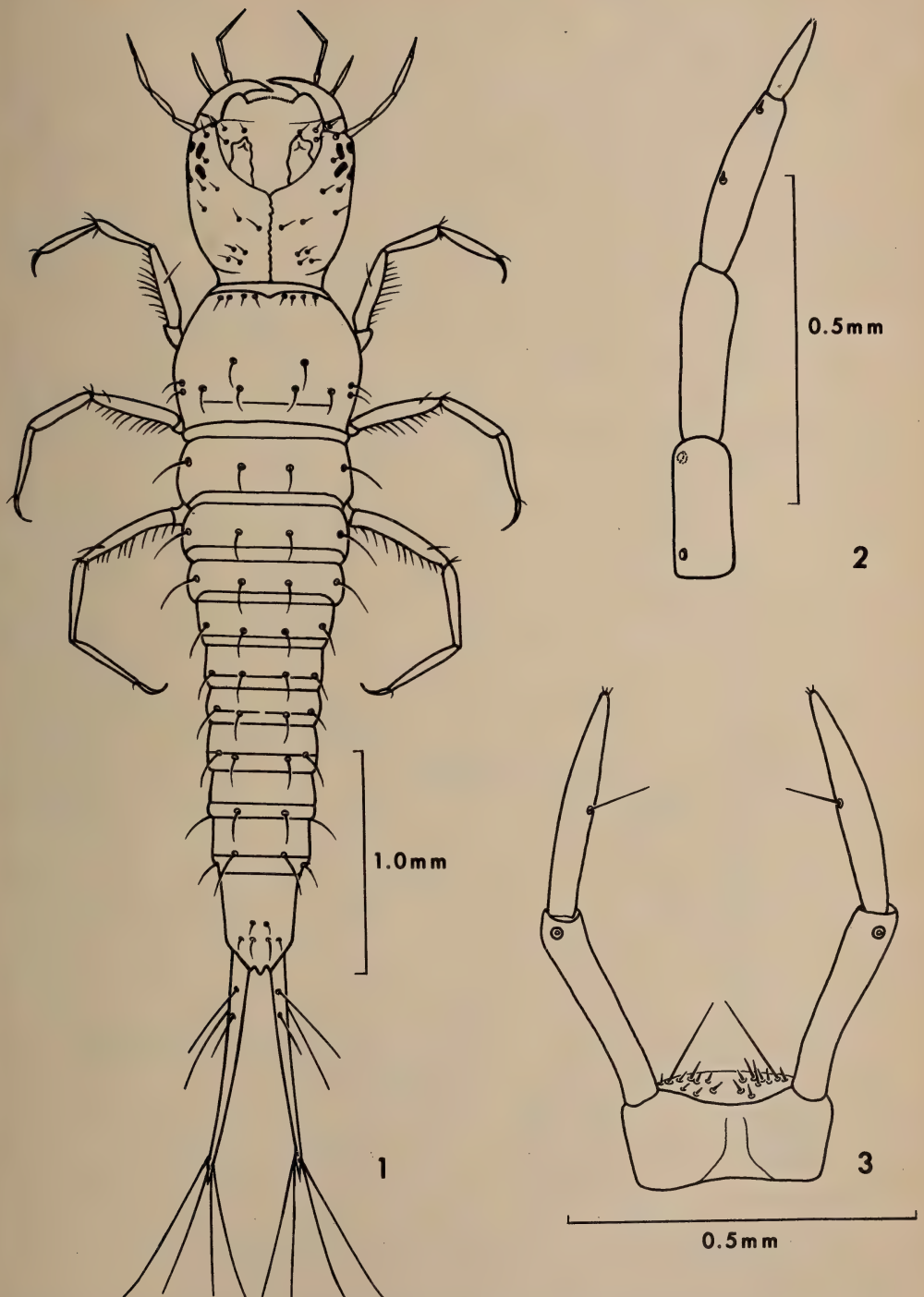
Second Instar

Though the larva is similar in form to that of the first instar, there are important differences. On the head, the frontal tubercle is absent, but on each side 8 or 9 temporal spines are now present. Also, both the seventh and eighth abdominal segments are entirely sclerotized. In some specimens, dark spots in the integument, near the antero-lateral angles of the first seven abdominal tergites mark the sites of additional spiracles. Terminal hairs on the cercus have shortened by a third of their length, and the lateral setae are less than one-half as long as the eighth abdominal tergite.

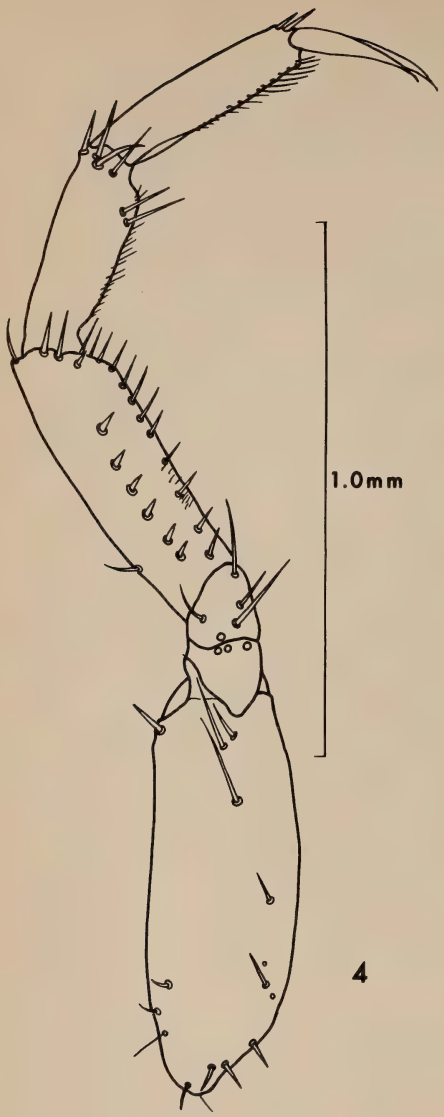
Mean length 11.26±1.41 mm, head width 1.59±0.03; head length 1.78 ±0.04 mm.

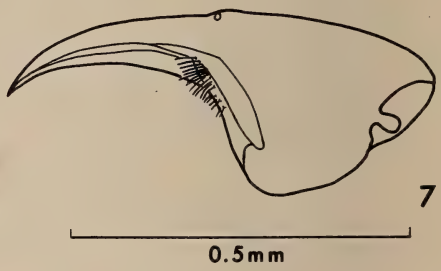
Third Instar (Figures 9 to 15, and 82)

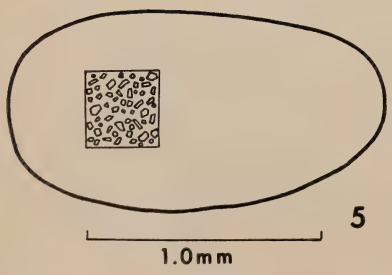
Larva campodeiform, though more spindle-shaped than depressed (Figure 82); widest at the mesonotum and tapering posteriorly, the thoracic tergites forming a

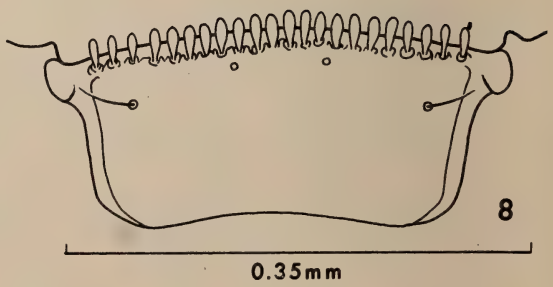


FIGURES 1-3. *Agabus erichsoni*. First instar: 1, larva, dorsal view; 2, right antenna; 3, labium ventral.

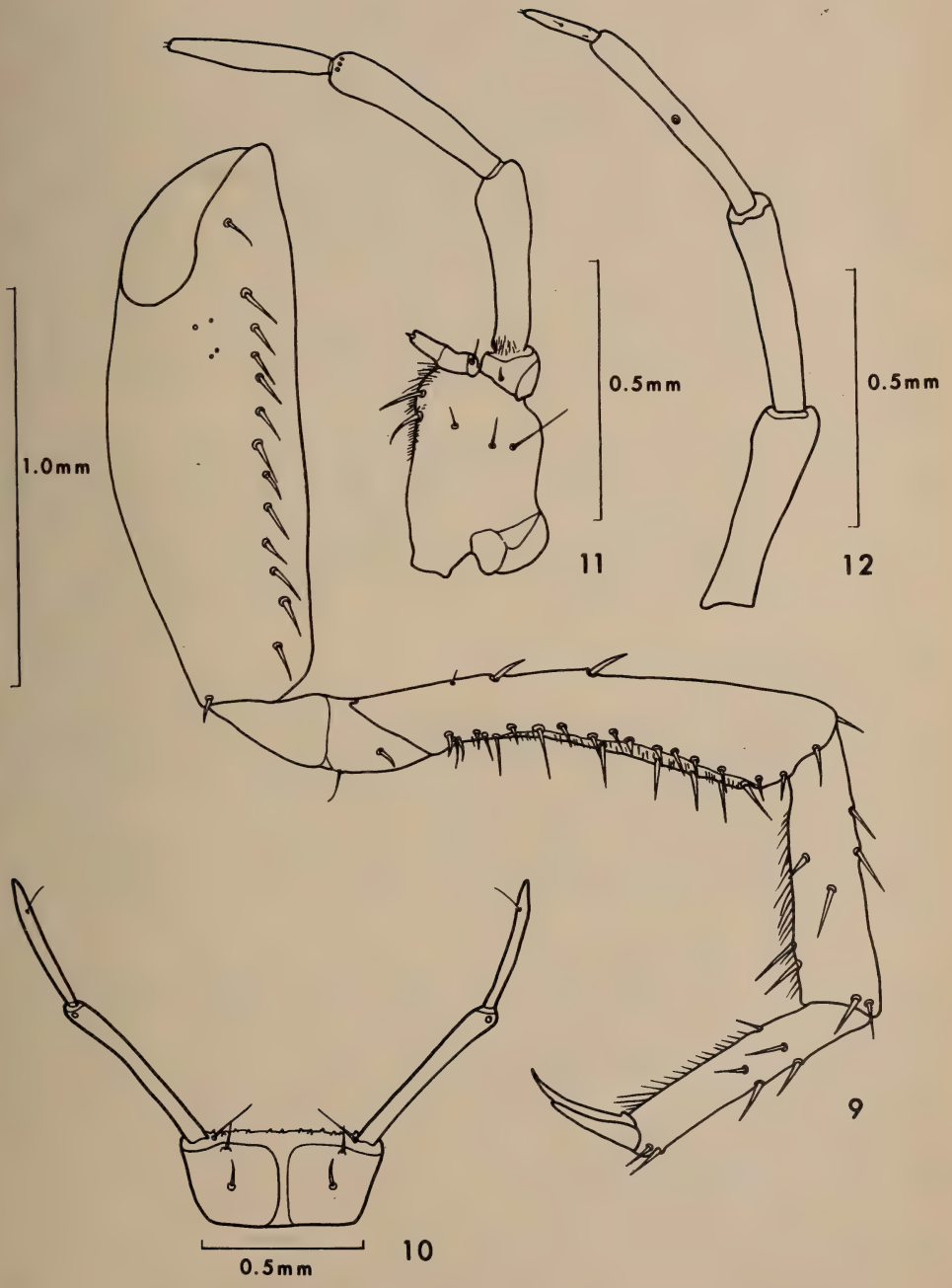








FIGURES 4-8. *Agabus erichsoni*. First instar: 4, right front leg, anterior view; 5, egg showing section of chorion (× 270); 6, first-instar: right maxilla; 7, right mandible; 8, row of clypeal setae.



FIGURES 9-12. *Agabus erichsoni*. Third instar: 9, right front leg; 10, labium ventral view; 11, right maxilla; 12, right antenna.

shield over the legs. Well-developed spiracles present laterally near the anterior margin of the mesonotum and dorsally near the antero-lateral margins of abdominal tergites I — VI; terminal spiracles opening dorsally on VIII.

Head (Figure 13) subquadrate, longer than wide, less than twice as long as the epicranial suture. Margin of clypeus curved, twice as long as segment I of antenna, with 26 to 29 club-shaped, long setae and 10 to 17 shorter one between and behind. Labral ridge with six setae. Temporal spines, 7 or 8, crossing lateral margin of head at an angle. Ocular area black, with four dorsal and two lateral ocelli, all well separated. Antenna (Figure 12) less than two-thirds as long as the head; segments II and III sub-equal in length, III, three times as long as IV. Mandible (Figure 14) strongly falcate, three times as long as wide at base; dorsal cutting edge lined with minute teeth to apex. Maxilla (Figure 11) with trapezoidal stipes; palp, based on a palpiger, three-segmented, segment I as long as II; ventral surface of stipes covered with short hairs. Labium (Figure 10) with base less than half as long as wide; ligula absent; segment II of palp about two-thirds as long as I.

Thorax: pronotum almost twice as long as mesonotum, meso- and metanotum sub-equal; pronotum with a double row of long setae near the anterior margin, and with a posterior fringe of setae on this and succeeding tergites. Front femur (Figure 9) five-sixths as long as coxa and 2½ times as long as trochanter. Natatory hairs absent.

Abdomen with eight well-defined segments that appear tubular in cross section and that narrow progressively from the base; segment I sub-equal in length to II and one-half as long as VIII. Cercus (Fig. 15) longer than VIII, its lateral and terminal setae short, each equal to one-quarter its length. Dorsal setae of abdomen stronger and more abundant caudad; lateral setae the longest.

Length (18) 17.52±2.31 mm; head width 2.27±0.06 mm; head length 2.44±0.07 mm.

Pupa (Figures 16, 85)

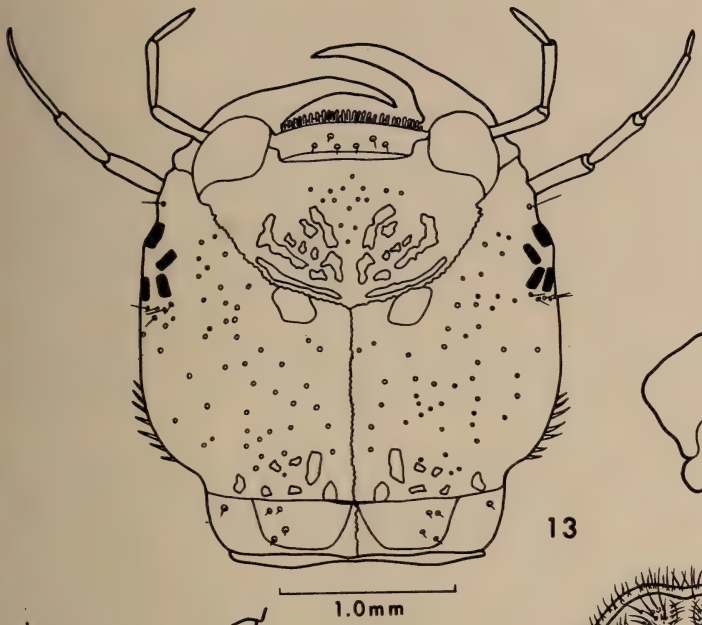
White. Sub-ovate, 2½ times as long as wide at the first abdominal segment. Pronotum projecting above the head. Antennae appearing from behind the compound eyes and bent downward under the front legs. Eyes light brown, darker in mature pupae. Spiracles present on abdominal segments I — VII. Femora lying at right angles to the long axis of the pupa; tibiae reflexed against the femora and curved inward so that the tarsi meet at the midline; middle tarsi extending to one-half the pupal length. Cercus dorsally sub-equal in length to the eighth abdominal tergite, slightly decurved one-third from base and tapering to a point.

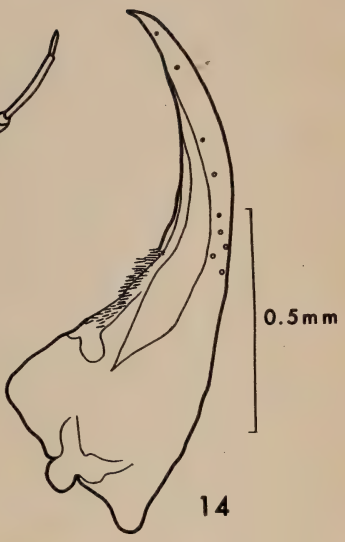
Head with short-based, setaceous styli (Figure 16). Similar but longer styli; up to 0.8 mm on the frontal crest and sides of the pronotum. Additional styli present on the thorax and on the elevated margins of the abdominal tergites; these are particularly abundant on the eighth segment where they are as long as those on the frontal crest. Cercus with a lateral stylus near the base and a ventral pair about half way from the apex. Abdomen ventrally with long styli, at least four to each segment.

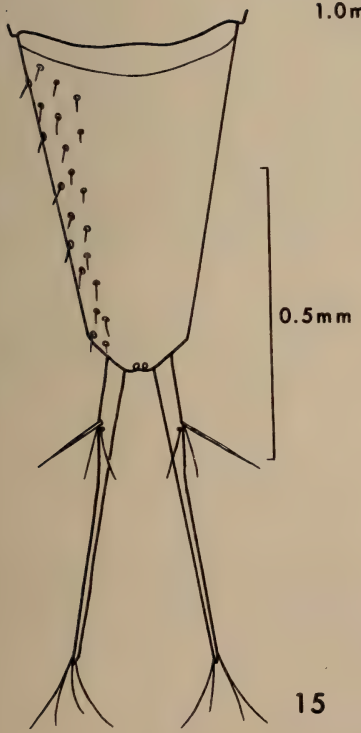
Mean length (6) 12.50 mm (11.72 — 12.90); width 4.90 mm (4.80 — 5.21); head width 2.90 mm (2.79 — 3.02).

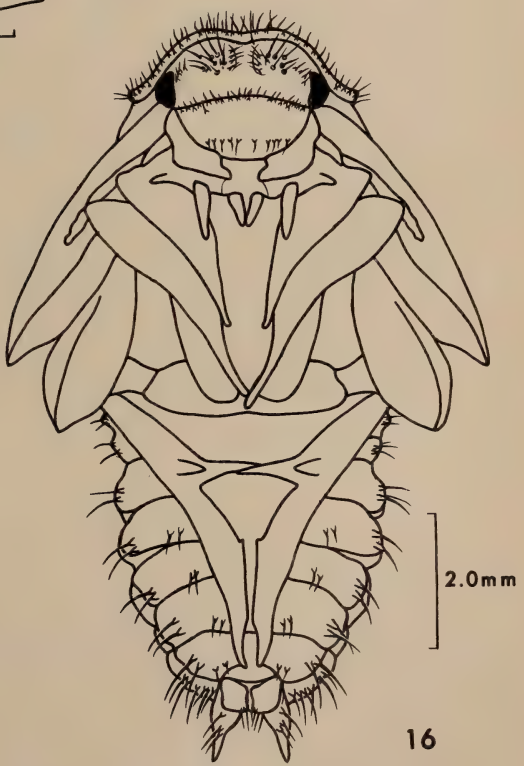
Habits and Life History

On May 24, collected females were found to contain 14 to 31 well developed eggs. In the laboratory from June 8 to June 13, they deposited eggs in groups of two and three among the root fibers of a moss, *Climacium dendroides* (Hedw.)









FIGURES 13-16. *Agabus erichsoni*. Third instar: 13, head, dorsal view; 14, right mandible; 15, eighth abdominal segment and cerci. 16, Pupa, ventral view.

Web. and Mohr, found in vernal pools, apparently being attached with an adhesive. Similar eggs were laid on the same moss by females confined to cages in natural pools. None of these hatched after incubation for 15 days though some segmentation was evident, but hatching occurred later after they had been exposed to 0°C for six months. After hatching, however, the weakened larvae were unable to capture prey and eventually died.

Eggs were also obtained in soil samples collected in late October from pool bottoms that had been without water since mid-July. After storage at 0°C for three months to fulfil the diapause requirements of the eggs, the samples were placed in trays and flooded with tap water. Vigorous first-instar larvae appeared in a few hours and began to feed on the newly hatched aedine larvae from the same soil. Thus, the eggs do not hatch in the pool soon after being laid, but like the eggs of *Agabus chalconatus* Panz. (Jackson, 1958) remain in the soil long after the supernatant water has disappeared.

Reared first-instar larvae ate an average of 6.90 early-instar *Aedes* daily; second- and third-instar 7.63 of larger prey. Larval feeding lasted from 21 to 30 days, and in one instance a predator completed each instar in 5, 8, and 10 days respectively, having fed on 252 *Aedes* in all.

Agabus erichsoni is univoltine. Overwintered adults were some of the earliest dytiscids observed in late March and April, when minimum pool temperatures were often 5°C. They were more active at night than during the day and were trapped more at pool margins than at the surface or in deep water (James, 1967).

Eggs were deposited on the bottom and lower margins of the pools in May and June. Some embryonic development occurred before they entered diapause and, in some years, before the pools were inundated in late fall. The eggs hatched in the following March or early April after pool bottoms had thawed and when first-stage aedine larvae and small Entomostraca were relatively abundant.

First- and second-instar larvae were collected in April and third-instar in late April and May over a total period of 5 to 6 weeks (James, 1961). No larvae could be dredged from the pools after mid-May, and presumably larvae had moved in to drier pool margins to pupate. Newly-formed pupae were found in earthen cells at the higher margins from June 10 to June 18 and teneral adults from June 14 to June 23. The almost circular pupal cells were lightly constructed depressions made in friable soil often under leafy humus.

Recently emerged adults either migrate or aestivate in nearby pools, but not in the bottom mud as reported by Wesenburg-Lund (1912). At Chatterton teneral adults were collected in aquatic traps in June and remained until the pools dried up. Extensive sampling of the pool sites later in the summer indicated that they do not aestivate in the soil.

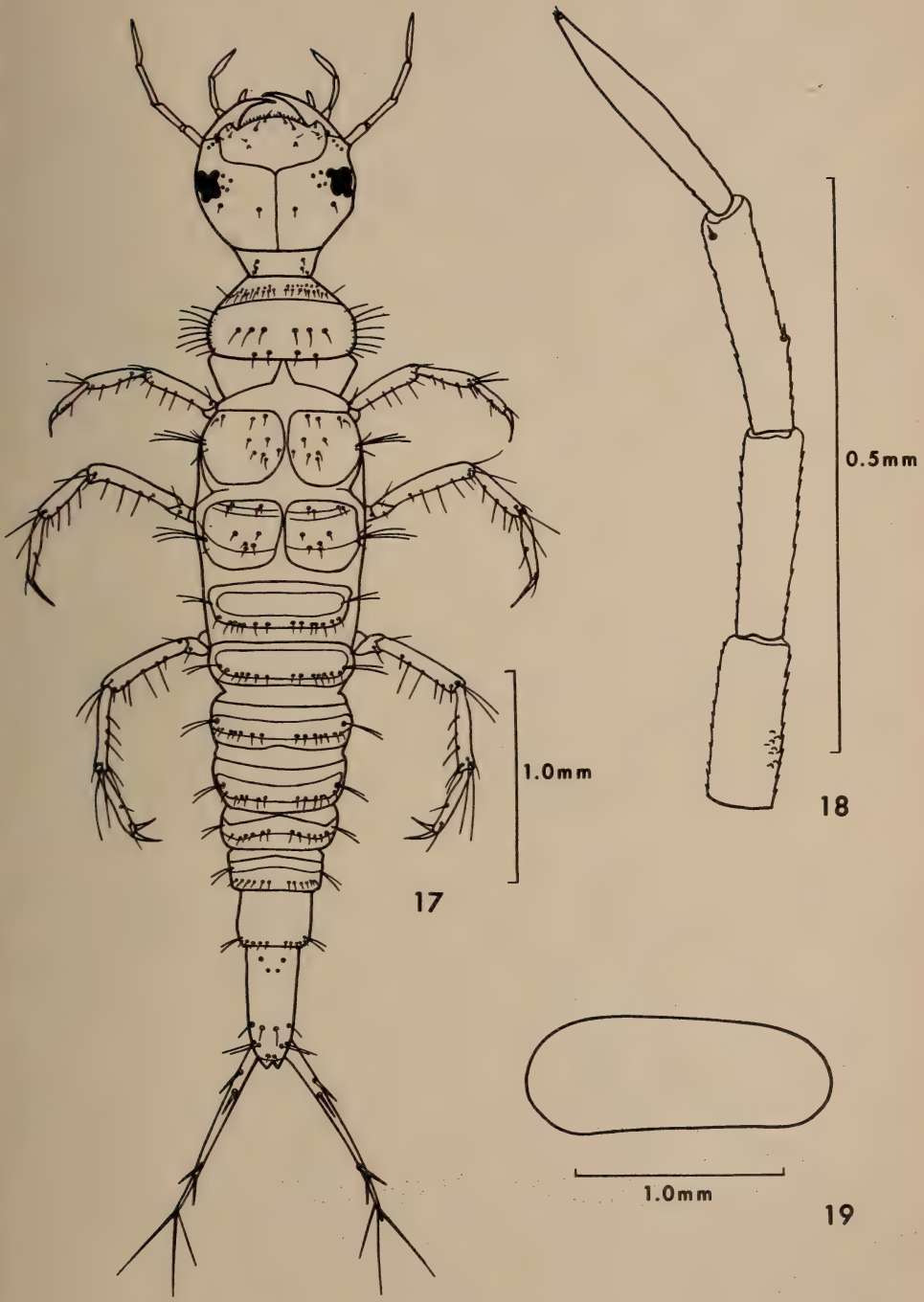
Rhantus binotatus (Harris), 1828

Egg (Figures 19 and 79)

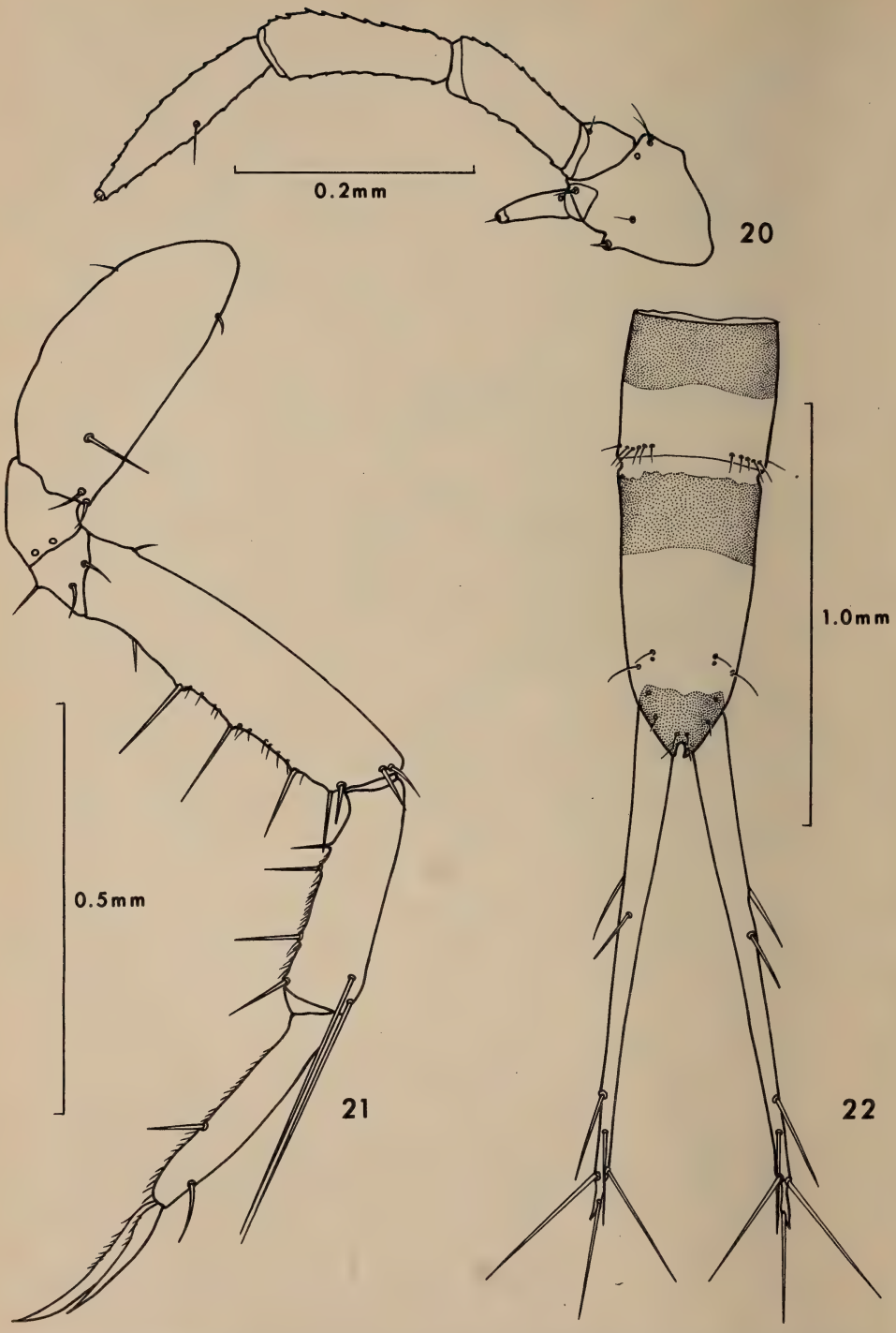
Elongate oval, broader at the anterior end and slightly kidney-shaped. Pale yellow when deposited, becoming grayish with development. Chorion thin, pliable. Mean length (5) 1.50 mm (1.48 — 1.59); greatest diameter 0.56 mm (0.53 — 0.58).

First Instar (Figures 17, 18, 20 to 22, 24 to 26, 34)

Head, excepting collar, almost circular as seen from above (Figure 17), wider than the body in newly-hatched larvae. Fronto-clypeal plate broadly triangular, strongly curving in front; epicranial suture more than half as long as head; frontal



FIGURES 17-19. *Rhantus binotatus*. First instar: 17, larva, dorsal view; 18, right antenna. 19, egg.



FIGURES 20-22. *Rhantus binotatus*. First instar: 20, right maxilla; 21, right front leg, posterior view; 22, terminal segments of abdomen.

tubercle with a short, stout spine. Ocular area with three pairs of ocelli on a dark patch: dorsal ocelli separated from each other by half their length, the laterals by a full length, and the short ventrals by twice their length. Margin of clypeus arcuate, fringed with 16 to 18 club-shaped setae on conical bases one-half their length (Figure 24). Antenna four-segmented, not quite as long as head (9:10), second and third segment sub-equal in length, apical the longest (Figure 18). Mandible (Figure 25) falcate, tapering to a sharp point, 2½ times as long as wide at base. Maxilla (Figure 20) with a short cardo, broad stripes, and robust palpiger and palp; length of palpal segments in the ratio of 5:6:7; galea, including a short spine, half as long as the first segment of the palp. Labium (Figure 26) with a pair of two-jointed palps, the apical segment slightly longer; mentum rectangular, almost three times as wide as long; ligula absent.

Pronotum more than twice as long as mesonotum; meso- and metanotum sub-equal. Coxa in front legs twice as long as the trochanter (Figure 21), tibia as long as the tarsus; swimming hairs absent. Abdomen tubular, gradually tapering from the base; apical segment twice as long as the penultimate and almost half as long as the cercus. Cerci (Figure 22) each with one pair of short setae, situated about one-third their length from the base, a distal pair, and three terminal setae each 0.5 mm long.

Mean length (8) 4.50 mm (3.51 — 5.54); head width 0.70 mm (0.68 — 0.80); head length 0.78 mm (0.61 — 0.90).

Second Instar

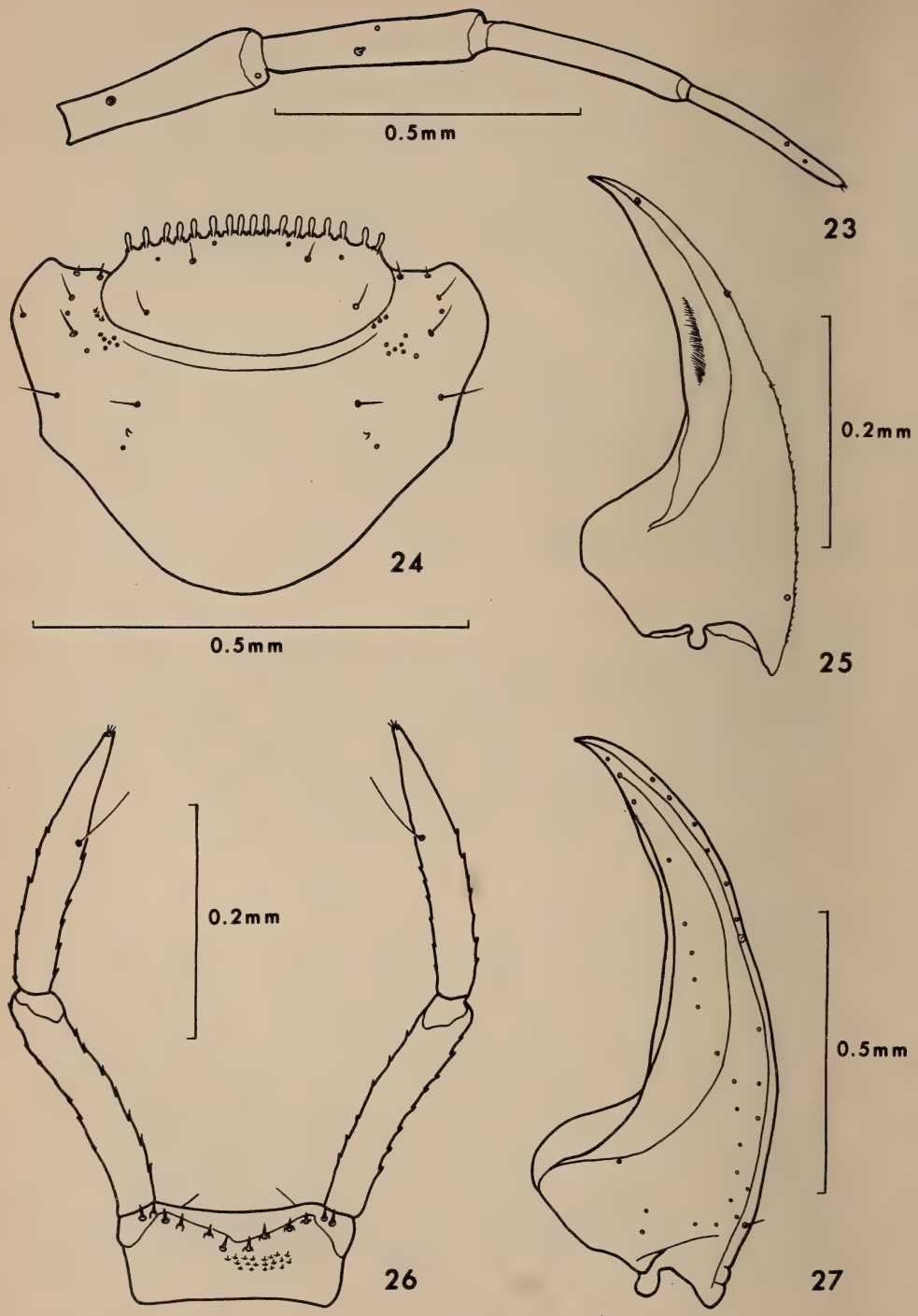
This stage differs markedly from the former. The thorax, particularly the prothorax, is laterally compressed and strongly arched dorsally. Frontal tubercles are absent from the head, but 7 to 9 temporal spines are now evident. The apical abdominal segment is 2½ times as long as the penultimate and more than half as long as the cerci. Numerous secondary setae are present on the cercus, and the legs are provided with swimming hairs on the femur, tibia, and tarsus.

Mean length (5) 7.18 mm (6.89 — 7.53); head width 1.19 mm (1.11 — 1.27); head length 1.32 mm (1.13 — 1.43).

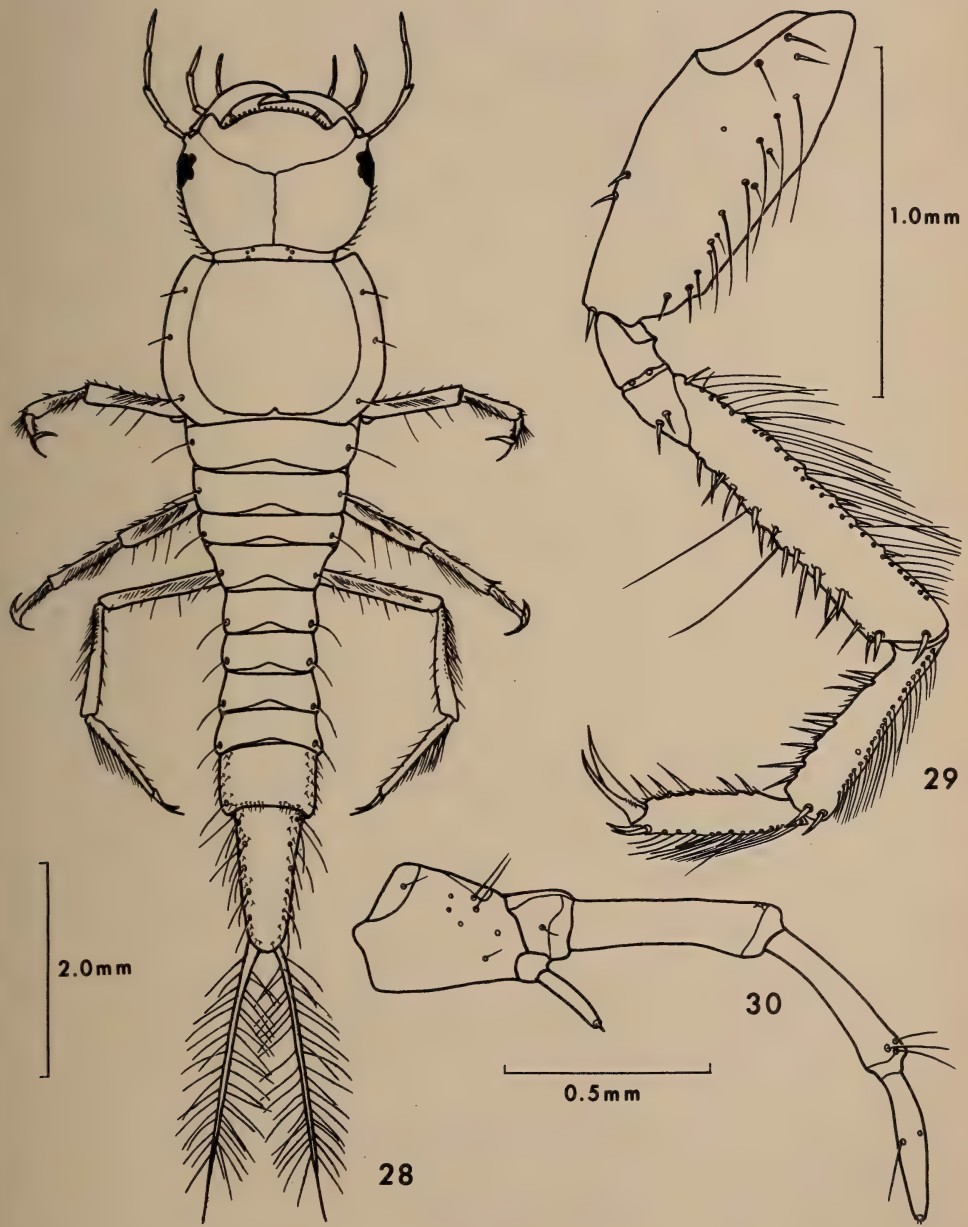
Third Instar (Figures 23, and 27 to 33)

Head sub-quadrate (Figures 28, 31), slightly longer than wide; epicranial suture more than half as long as the head. Margin of clypeus 2½ times as long as segment I of antenna and lined with abundant clavate setae. Temporal spines, 9 or 10, originating above the collar and extending along the postero-lateral margins of the head almost to the lateral ocelli. Ocular area with two pairs of dorsal and one pair of lateral ocelli; inner dorsal ocelli close together, middle pair more widely separated. Antenna (Figure 23) four-segmented, linear, two-thirds as long as the head; segments I, II, and III sub-equal in length, IV the shortest. Mandible (Figure 27) falcate more than three times longer than wide at the base. Maxilla (Figure 30) three-fifths as long as the head; cardo short, stipes trapezoidal and elongate; segments I, II and III of the palp in ratios of 5: 4.5 : 4. Labium (Figure 32) with a sub-rectangular mentum less than three times as wide as long; palp 2-segmented; apical segment almost three-quarters as long as the first (23:32); ligula absent.

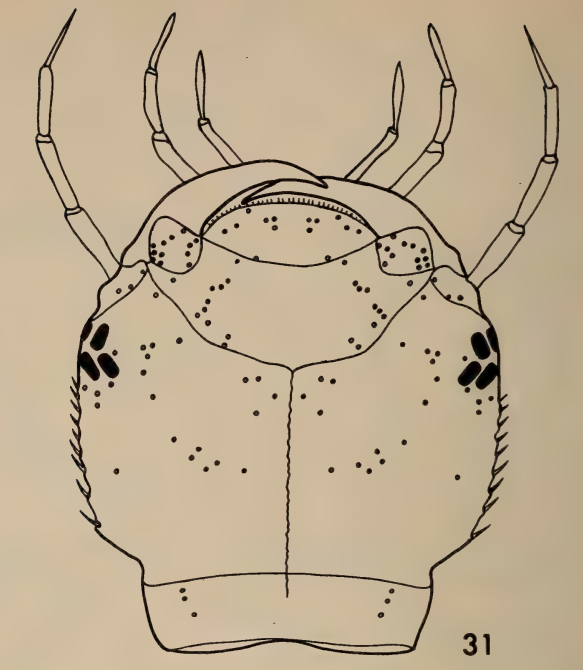
Thorax and abdominal segments I to VI laterally compressed, the latter acutely arched. A pair of spiracles evident beneath and at the sides of the mesonotum; abdominal spiracles near the margins of tergites I to VII and dorsally on VIII.

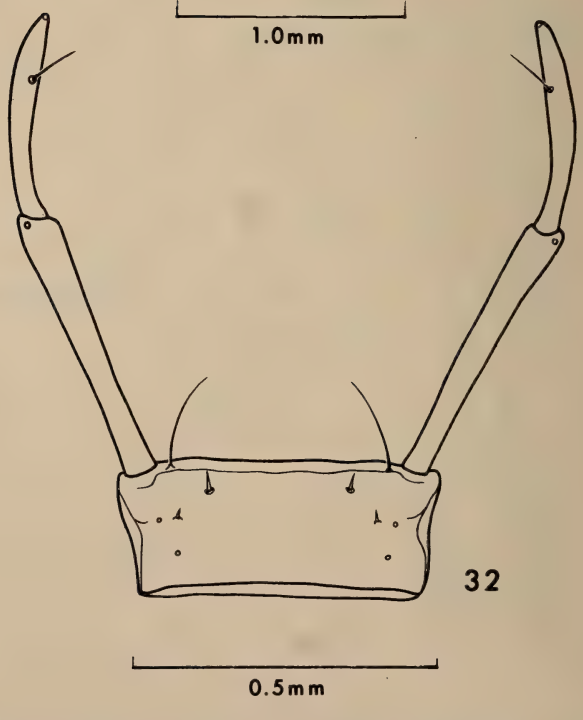


FIGURES 23-27. *Rhantus binotatus*. Third instar: 23, left antenna. First instar: 24, clypeus with fringe of setae; 25, right mandible; 26, labium, ventral view. 27, right mandible of third instar.

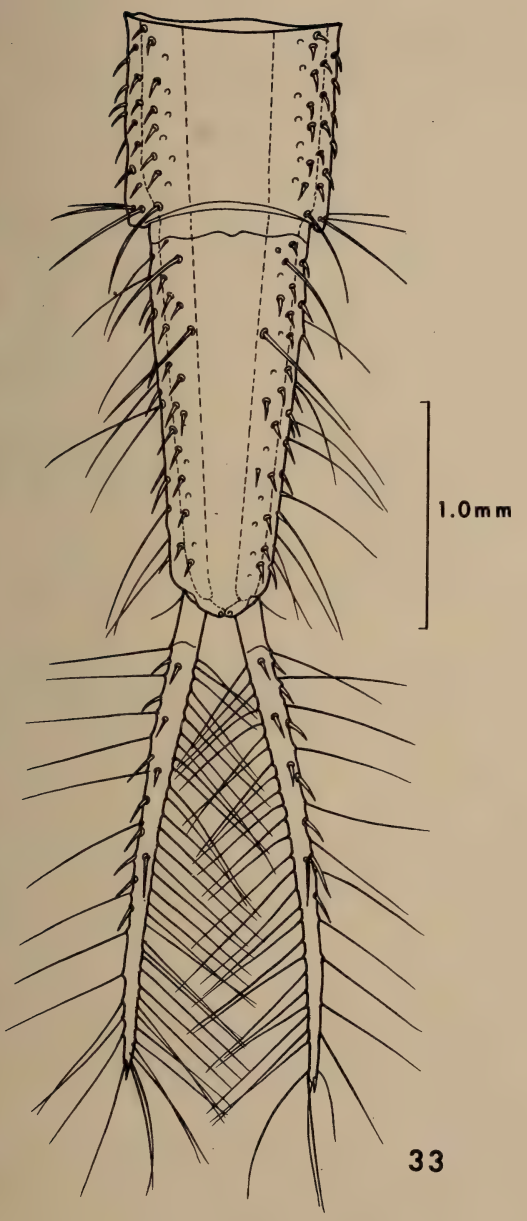


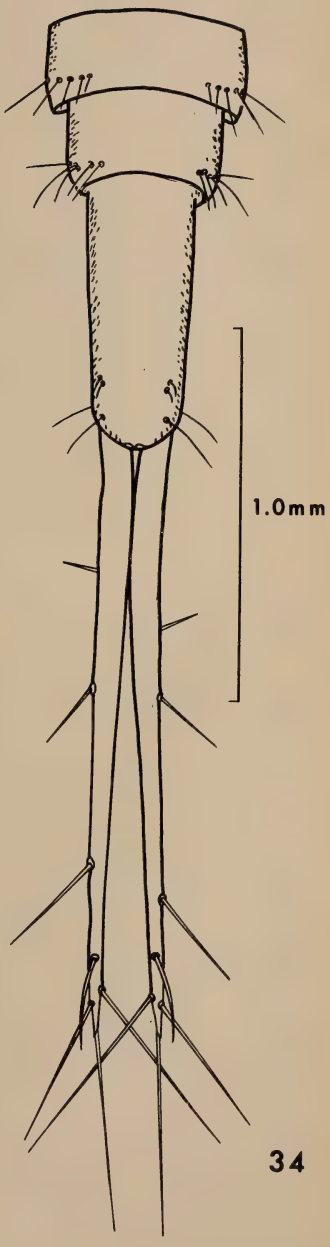
FIGURES 28-30. *Rhantus binotatus*. Third instar: 28, larva, dorsal view; 29, right front leg, posterior view; 30, right maxilla, ventral.





FIGURES 31-32. *Rhantus binotatus.* Third instar: 31, head; 32, labium, ventral.





FIGURES 33-34. *Rhantus binotatus*. Third instar: 33, terminal abdominal segments. *Colymbetes sculptilis*. First instar: 34, terminal abdominal segments.

Coxa of front legs (Figure 29) about 2-1/3 times longer than the trochanter and sub-equal to the femur; femur twice as long as tarsus. All legs with long, swimming hairs on the last three segments.

Abdominal segments VII and VIII completely sclerotized; segment VII less than half as long as VIII, not including cerci (Figure 33). Cerci fringed laterally with about three times as many setae on the inside as on the outside; each cercus also characterized by three short and one long dorsal setae and by a strong ventral spine two-fifths the distance from the base to apex.

Mean length (6) 13.41 mm (11.23 — 15.20); head width 1.85 mm (1.70 — 1.94); head length 2.08 mm (1.91 — 2.19).

Habits and Life History

Little is known about this species. Eggs were found attached to a twig in a jar containing a female collected in a vernal pool at Cordova Mines on June 1. Other eggs were deposited in the laboratory on a sedge leaf and by June 13, seven had been laid. According to Balduff (1935), some species stick their eggs to plant surfaces; others glue them to rootlets (Williams, 1936).

The newly-deposited eggs were isolated and hatched in 3 to 4 days. Larvae spent an average of 4.6 days in the first instar and 7.2 in the second. Third-instar larvae lived from 3 to 10 days but failed to pupate.

Adults of this species were not uncommon in New York State (Leonard, 1926). At Chatterton they were no more abundant than *Rhantus binotatus* (Fab.), another predator of aedine larvae and less common than *Rhantus tostus* Lee. which inhabits permanent ponds in the Belleville district.

Colymbetes sculptilis Harris, 1829

Egg (Figure 38)

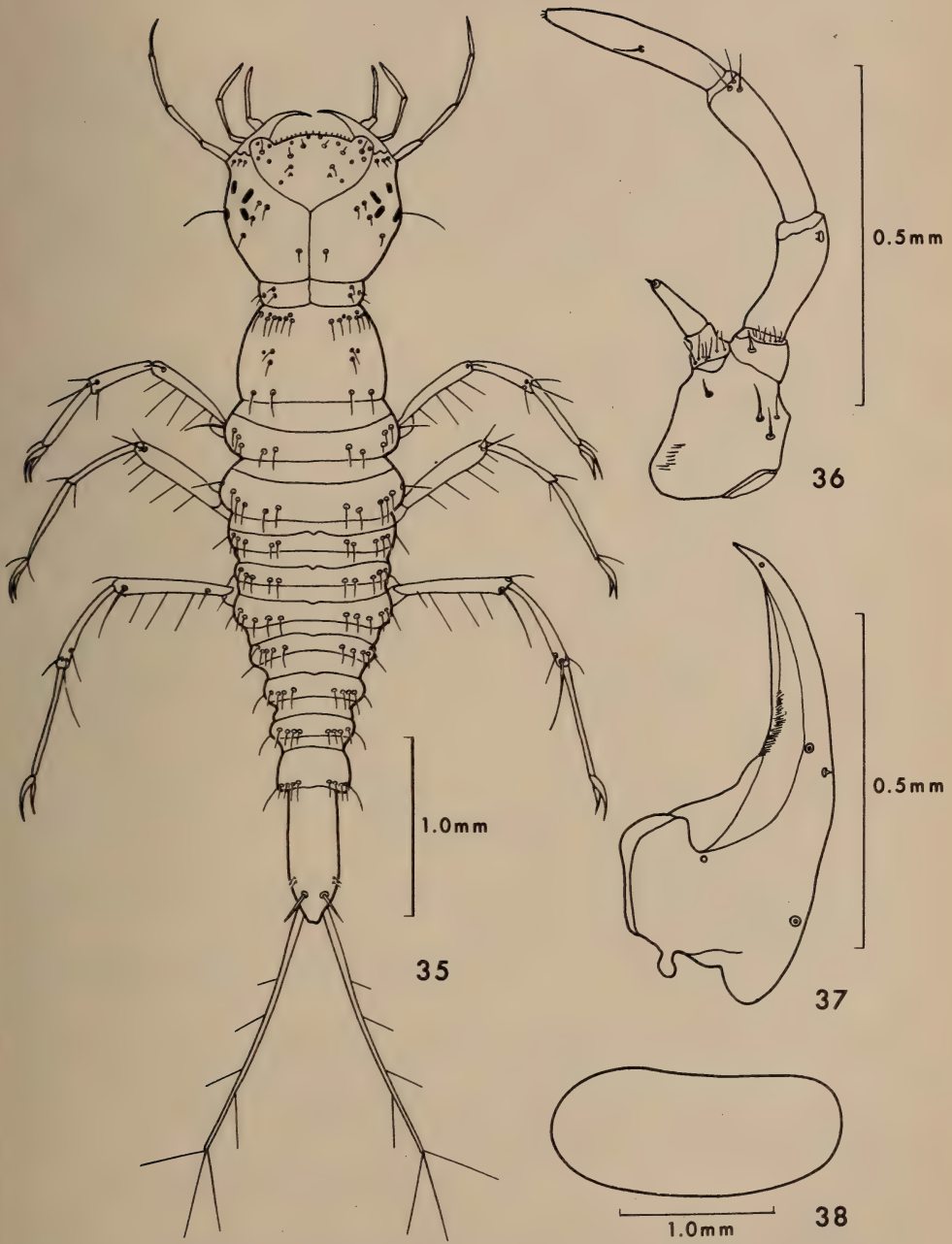
Elongate oval, somewhat kidney-shaped and broader toward the anterior end. Pale yellow when deposited, with a smooth thin and pliable chorion. Mean length 1.81 mm (1.74 — 1.86); greatest diameter 0.74 mm (0.73 — 0.76).

First Instar (Figures 34 to 37, 39, 44, 47)

Head pale-gray, wider than prothorax, and except for collar, circular in dorsal view (Figure 35). Fronto-clypeal plate more or less triangular; rounded margin of clypeus with 13 or 14 short, clavate setae set in cups; frontal tubercles each with a short, strong spine. Ocular area with two dorsal and one ventral pair of ocelli, the inner dorsals close together. Antenna (Figure 47) four-segmented, as long as the head; segment II as long as IV, but less than III. Mandible (Figure 37) falcate, 2½ times longer than wide at base. Maxilla (Figure 36) with a broad stipes, one-segmented galea, and three-segmented palp based on a palpiger; cardo very short; galea one-half as long as segment I of palp. Labium (Figure 44) with a pair of two-segmented palps; segment I as long as II; mentum sub-rectangular, 2⅓ times wider than long; ligula absent.

Thorax and abdomen more cylindrical than depressed in cross section. Prothorax wider than long and about twice as long as the mesonotum. Trochanter of front legs (Figure 39) two-fifths as long as coxa; tibia and tarsus sub-equal. Natatory hairs absent on all legs.

Abdomen tapering sharply from segments I to VI, then gradually; segment VIII three times as long as VII and entirely sclerotized. Cercus (Figure 34) with pairs of dorsal and lateral setae as well as three terminals each one-third as long as the cercus itself.



FIGURES 35-38. *Colymbetes sculptilis*. First instar: 35, larva, dorsal view; 36, right maxilla; 37, right mandible. 38, egg.

Mean length (13) 7.05±0.93 mm; head width 1.21±0.03 mm; head length 1.25±0.04 mm. Mean head width (6) shortly after hatching 1.09 mm (0.92 — 1.19); head length 1.02 mm (0.95 — 1.11).

Second Instar

At this stage the larva has about doubled its length and differs from the first-instar larva in many ways. The head appears more square than circular, temporal spines are present, and the frontal tubercles have disappeared. The development of incipient lateral spiracles is indicated by dark specks in the membranous tissue between the pro- and mesothorax, and in similar lateral spots between abdominal tergites I to VI, as well as mid-ventrally on the now fully sclerotized segment VIII. Finally, the cercus has numerous secondary setae.

Mean length (14) 12.40±1.65 mm; head width 1.97±0.07 mm; head length 2.13±0.08 mm.

Third Instar (Figures 40 to 43, 45, 48, 49, 76, 83)

Head sub-quadrate (Figures 45, 83) about as wide as long at a point midway between the ocellar patch and the collar. Temporal spines 8 to 11, in the same plane as the mandibles and along a line curving toward the lowest pair of ocelli. Clypeus arcuate, more than twice the length of segment I of antenna and with numerous clavate setae (Figure 41). Four setae on each side of the labral ridge, other dorsal setae as illustrated. Ocular area with four dorsal and two lateral ocelli, the inner dorsals close together. Antenna linear (Figure 48), three-fifths as long as the head; segment I longer than IV. Mandible strongly curved (Figure 42) three times as long as wide at base. Stipes of maxilla (Figure 49) broad near its junction with the cardo, then narrowing; palp three-segmented; segment I longer than II (6:5). Labium (Figure 76) with mentum about three times as wide as long; segment II of palp two-thirds as long as I; mentum ventrally with five short spines and one long seta on each side near the anterior margin.

Pronotum, at the posterior angles, 1½ times wider than head, and three times longer than the mesonotum at the midline. Front leg (Figure 40) with trochanter one-third as long as coxa; tibia longer than tarsus (20:17). Natatory hairs present on femur, tibia and tarsus.

Abdomen tubular, tapering, the segments increasing in length posteriorly; apical tergite 2½ times longer than penultimate and sub-equal to cerci (Figure 43). Segments VII and VIII fully sclerotized.

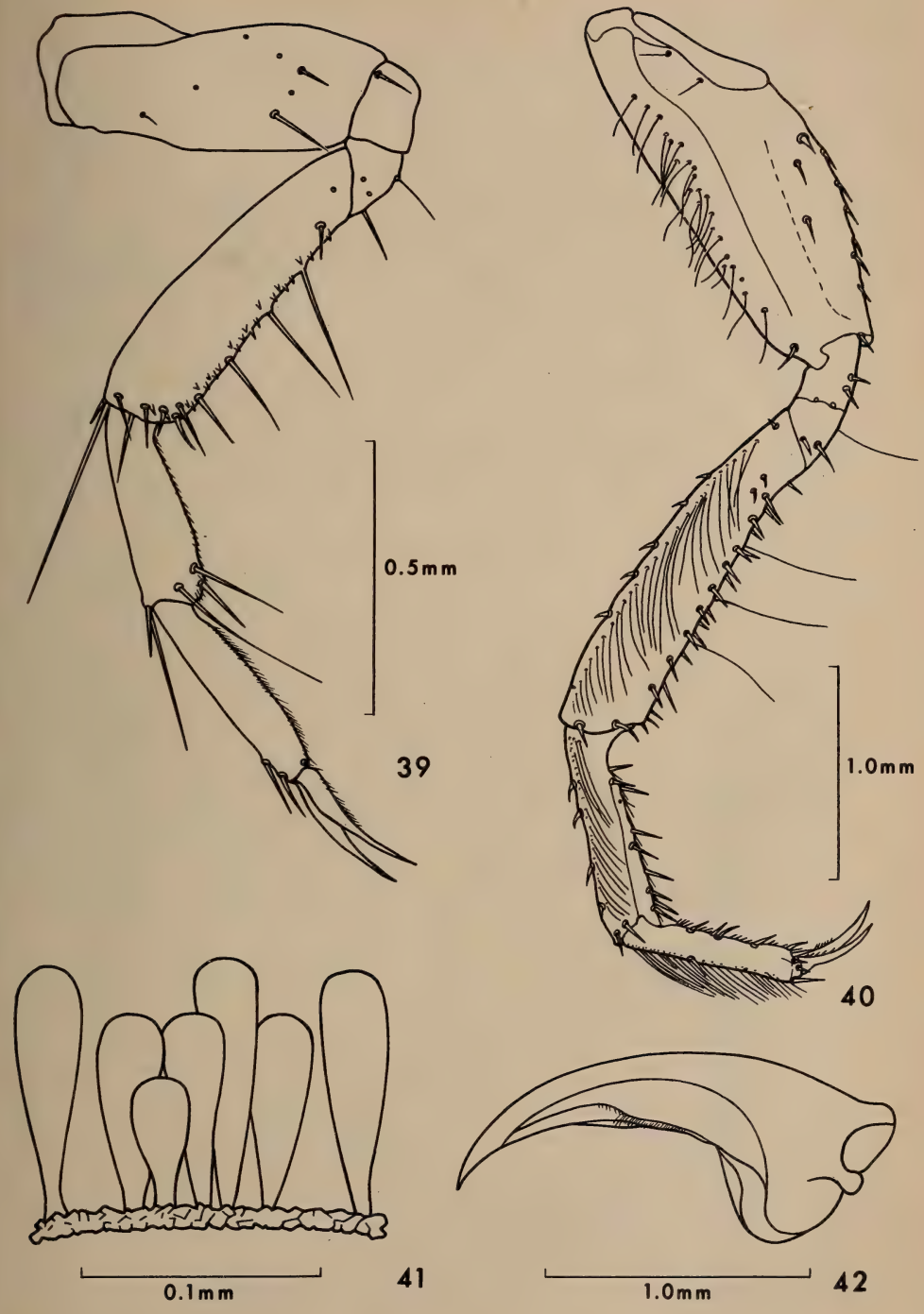
Spiracles present ventrally on the mesothorax near the lateral angle of the tergite; lateral spiracles on abdominal segments I - VII and a dorso-lateral pair on VIII.

Body setae progressively longer and more abundant caudad, especially on the abdomen; apical segment entirely covered with strong setae, some as long as those on the cerci; long, but fewer setae on sternites III-VI.

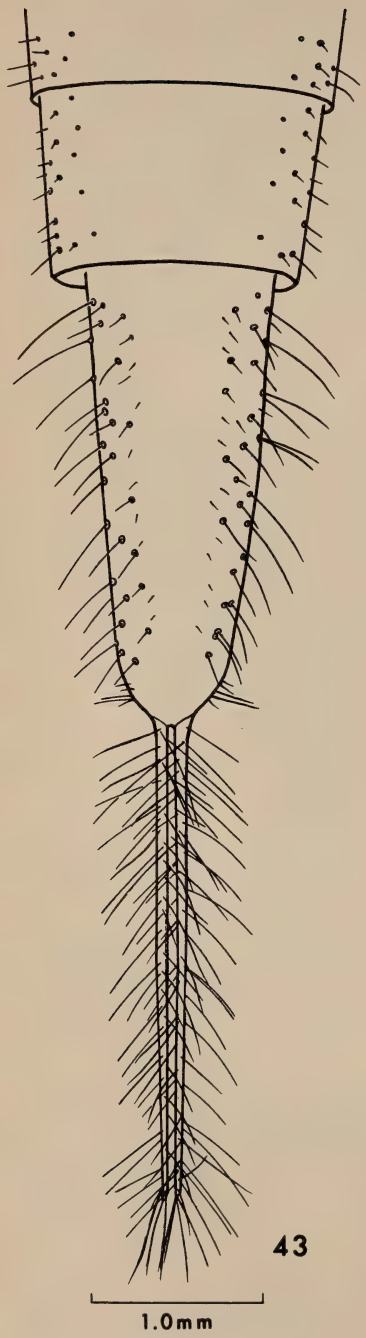
Mean length (25) 21.19±2.16 mm; head width 3.29±0.20 mm; head length 3.51±0.21 mm.

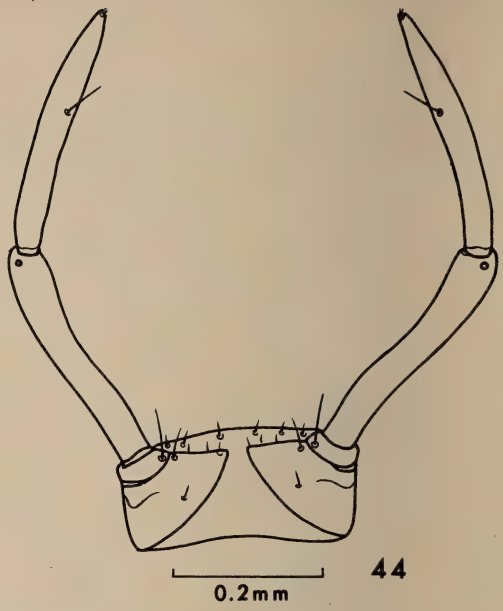
Pupa (Figure 46)

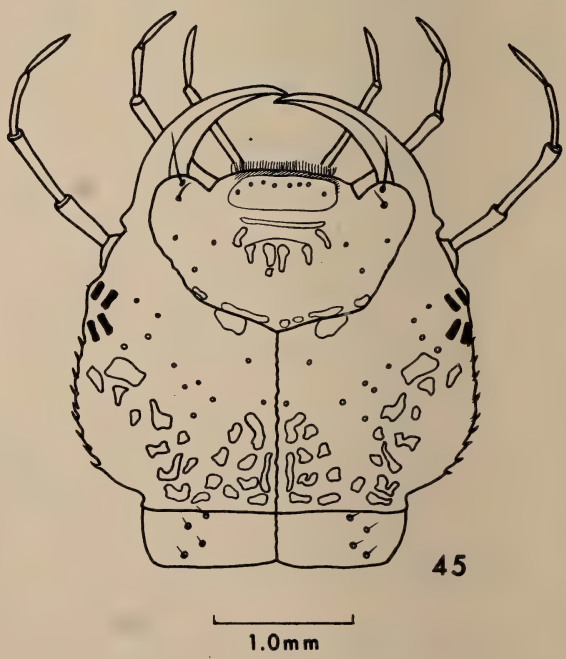
White. Elongate, depressed, more than twice as long as wide. Spiracles evident on the lateral margins of abdominal segments I-VII. Femora of front and middle legs at right angles to the long axis and adpressed to the elytral pads below, the remaining segments reflexed to meet at the midline. Hind femora hidden beneath wing pads, with the tibiae reflexed diagonally and the tarsi meeting near



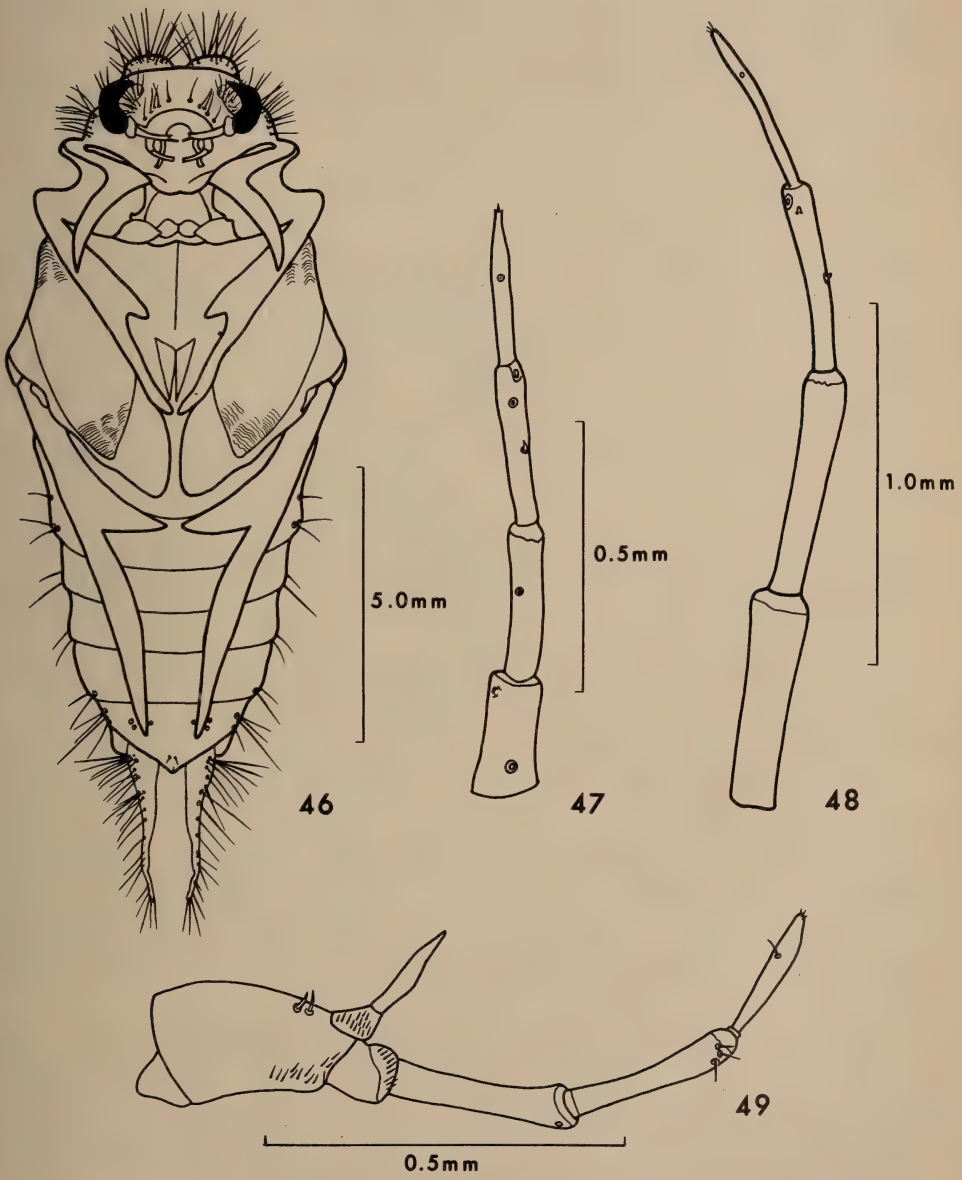
FIGURES 39-42. *Colymbetes sculptilis*. First instar: 39, right front leg, anterior view; third instar: 40, right front leg; 41, clypeal setae; 42, right mandible.







FIGURES 43-45. *Colymbetes sculptilis*. Third instar: 43, terminal abdominal segments; first instar: 44, labium, ventral view; third instar: 45, head.



FIGURES 46-49. *Colymbetes sculptilis*. 46, pupa; first instar: 47, right antenna; third instar: 48, right antenna; 49, right maxilla.

the end of the abdomen. Antennae curved downward below the eyes and apparently beneath the femora of the front and middle legs. Elytral sculpture apparent through pupal skin in some specimens.

Numerous dorsal styli present, each on a short conical base. Head with a deeply emarginate frontal crest that extends to the eye on each side; frontal styli 0.9 mm long. Elevated tubercles with long styli below the eyes; 5 or 6 labral styli. Pronotum thickly fringed in front and at the posterior margins; dorsal plate with a few isolated styli. Long styli present near the rear margins of the metanotum and abdominal segments and also on the cerci.

Mean length 14.89 mm (14.60 — 15.41); maximum width 6.92 mm (6.53 — 7.44); head width 3.73 mm (3.64 — 3.81); width of pronotum 4.66 (4.35 — 4.98).

Habits and Life History

Eggs of a European species, *Colymbetes fuscus* L., are laid on leaves of aquatic plants (Balduff, 1935). No intact eggs were collected at Chatterton on vegetation, though the remains of similar eggs were found attached to sedge leaves. Their shape, dimensions, and spacing suggested those of *C. sculptilis.* In the laboratory, 84 eggs were deposited with a strong adhesive to both sides of a paper label in a rearing jar from April 2 to April 8; similar eggs were found on the plastic lining of an outdoor test pool that contained only the species.

Eggs incubated at 19°C hatched in six days. The first larval stage was completed in 3 to 4 days, the second in 5 to 8, and the third in from 7 to 24 (mean 11.7).

Larvae were observed to crawl rather than swim over the pool bottom except when returning to the surface film for air. Third-instar larvae appeared to be active swimmers as many were collected in aquatic traps (James and Redner, 1965) placed near pool margins.

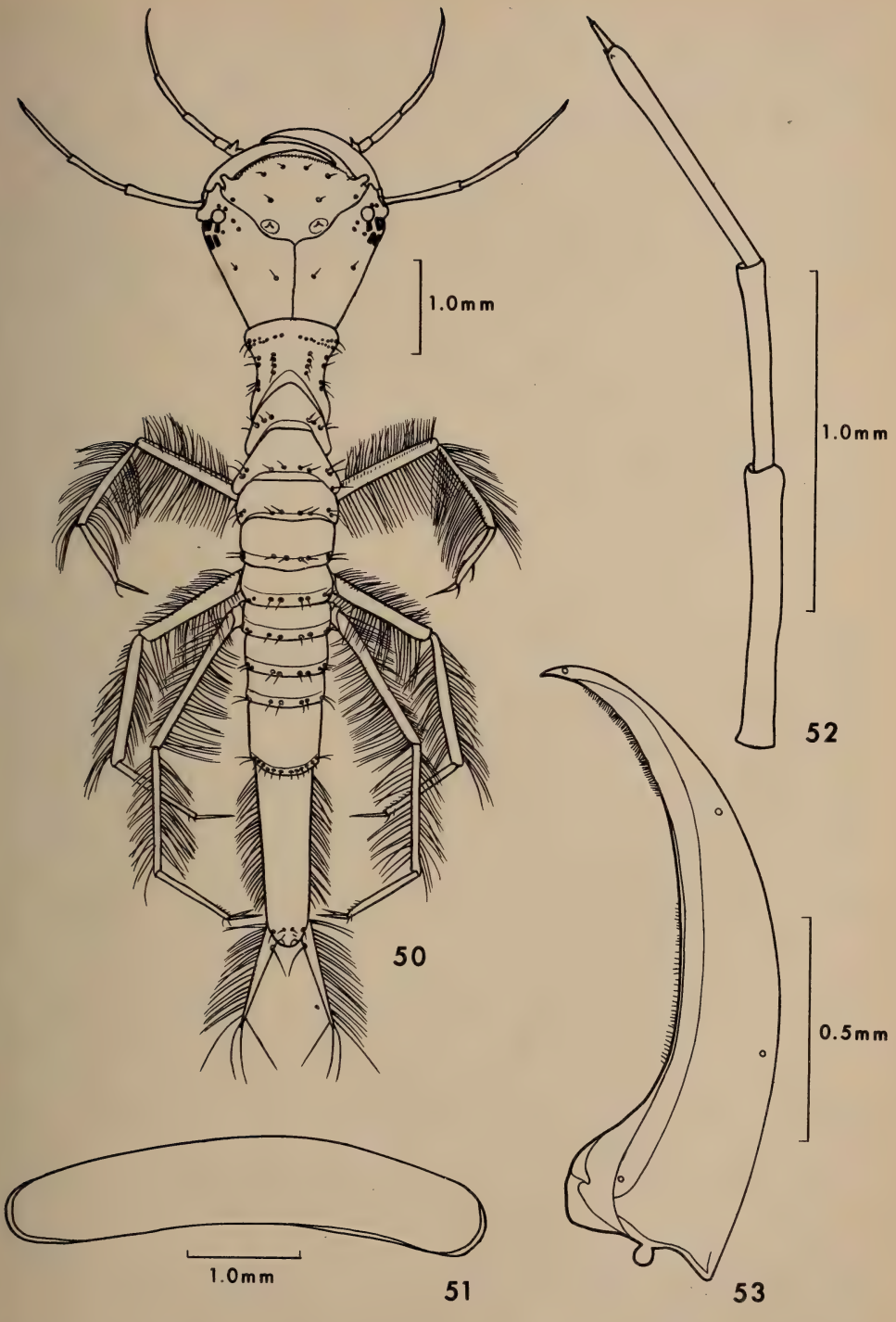
Adults appeared less active during the day than at night since only about half as many were trapped during these hours; in daylight they also occupied deeper water than did dark colored beetles such as *Agabus* and *Hydrochara.*

Baldruff reported that in Europe *Colymbetes fuscus* preyed on *Culex* larvae and small crustaceans. In Ontario it was found that both adults and larvae of *C. sculptilis* fed on aedine mosquitoes in natural pools (James, 1961, 1966) as well as on larger prey.

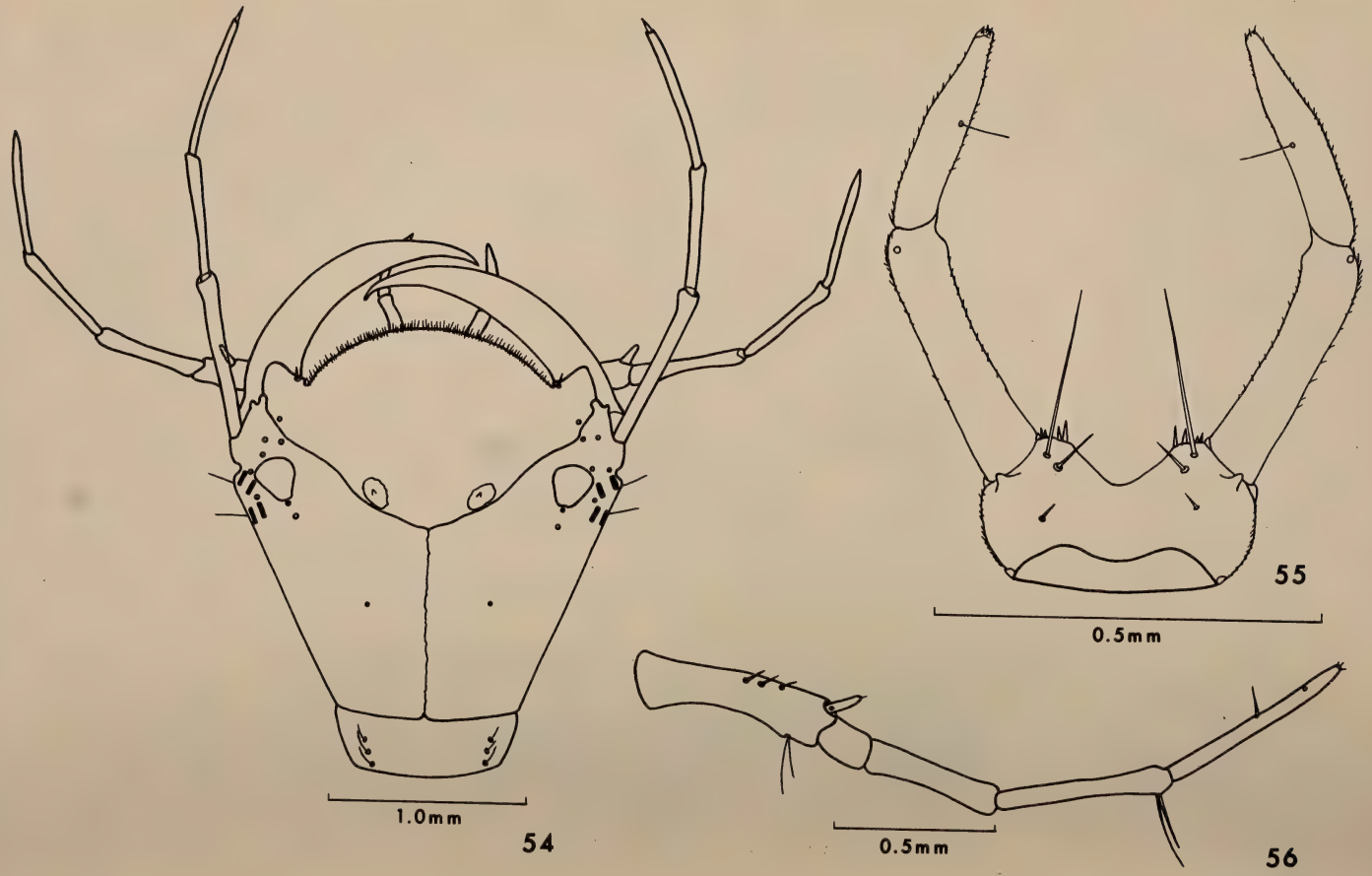
The feeding rate of adults was tested in four plastic-lined, outdoor pools (Briand, 1964). In each pool, 1,000 early-instar larvae of *Aedes stimulans* were exposed to four adults (2 ♂♂ + 2 ♀♀) of *C. sculptilis* for 13 days at a mean daily temperature of 10.7°C (range 7.2 — 13). The results were determined from the numbers of missing larvae less mortality in the control. Thus, in this environment, the mean number of Aedes lost daily per predator in the absence of other prey was 12.2 (11.5 — 13.1).

C. sculptilis is univoltine. Adults appeared first in late March and early April, usually a few days after the eggs of *Aedes stimulans* and *A. trichurus* had hatched. At this time daily temperatures were 3 to 13°C in pools where the margins often were still unthawed. Mating pairs were observed on April 12 in water at 12.8 and 13.5°C. Both sexes continued to occupy the pools until they dried up, usually in July.

The larval stages overlapped considerably. First-instar larvae were collected from April 7 to April 27, which suggests that some eggs had been deposited very early in the season. Second-instar larvae were present from April 26 to May 27, and third-instar from May 4 to June 20. Mature larvae left the water for the



FIGURES 50-53. *Dytiscus fasciventris*. 50, first-instar larva, dorsal view; 51, egg; first instar: 52, right antenna; 53, right mandible.



FIGURES 54-56. *Dytiscus fasciventris*. First instar: 54, head; 55, labium, ventral view; 56, right maxilla.

higher pool margins where they excavated shallow cells beneath leafy debris. Pupae appeared in early June and adults emerged toward the end of that month. In one instance pupation in the laboratory lasted eight days. As with other dytiscids, there was some evidence that adults leave drying pools for permanent water to overwinter, though some may reoccupy breeding habitats that are flooded in late autumn.

C. sculptilis was not abundant in vernal pools. In 1964, for example, adults and larvae of 15 species of water beetles were collected in traps from three pools, but only 6.7% were of this species. Similarly, area sampling during June and July indicated for *C. sculptilis* a mean population of 0.17/square meter (60 samples, 0.5 square meter) as compared to 2.2 for *Agabus erichsoni,* and 0.8 for *Hydrochara obtusata* Say.

Dytiscus fasciventris Say, 1824

Egg (Figures 51 and 81)

Elongate oval, slightly curving and broader toward the anterior end. Color pale yellow. Chorion smooth, transparent. Mean length of eggs laid in rearing jars (12) 4.32±0.04 mm; greatest diameter 0.83±0.03 mm. Length of eggs deposited in sedge leaf, near eclosion (Figure 81) 4.45 mm; greatest diameter 1.01 mm.

First Instar (Figures 50, 52 to 57, 59, 60)

Head (Figure 54) sub-triangular, narrow posteriorly and depressed; longer than wide. Fronto-clypeal plate broadly triangular, with a pair of oval tubercles on its lower margin, each with a median spine; epicranial suture more than half as long as head. Ocular area with three pairs of dark ocelli, the inner dorsal pair close together, the others farther apart; rudimentary visual organ or *tache oculaire* (Bertrand, 1928) situated behind the inner ocelli. Margin of clypeus strongly arcuate, with a fringe of clavate setae, each about 0.03 mm long (Figure 59). Antenna linear, four-segmented; segment I as long as III and eight times longer than IV. Mandible (Figure 53) narrowly falcate, more than three times as long as wide at base. Maxilla linear (Figure 56); stipes 3½ times as long as wide; segment I of palp four-fifths as long as II. Labium (Figure 55) with a pair of robust palps arising from a deeply emarginate mentum; segment I of palp longer than II (6:5); conical tubercle near the base of each palp present ventrally. Ligula wanting.

Body fusiform, somewhat depressed. Pronotum twice as long as mesonotum and about three times as long as abdominal tergite I. Femur of front leg 2½ times longer than trochanter (Figure 57); tarsus two-thirds as long as tibia. Long natatory hairs present on femur and tibia.

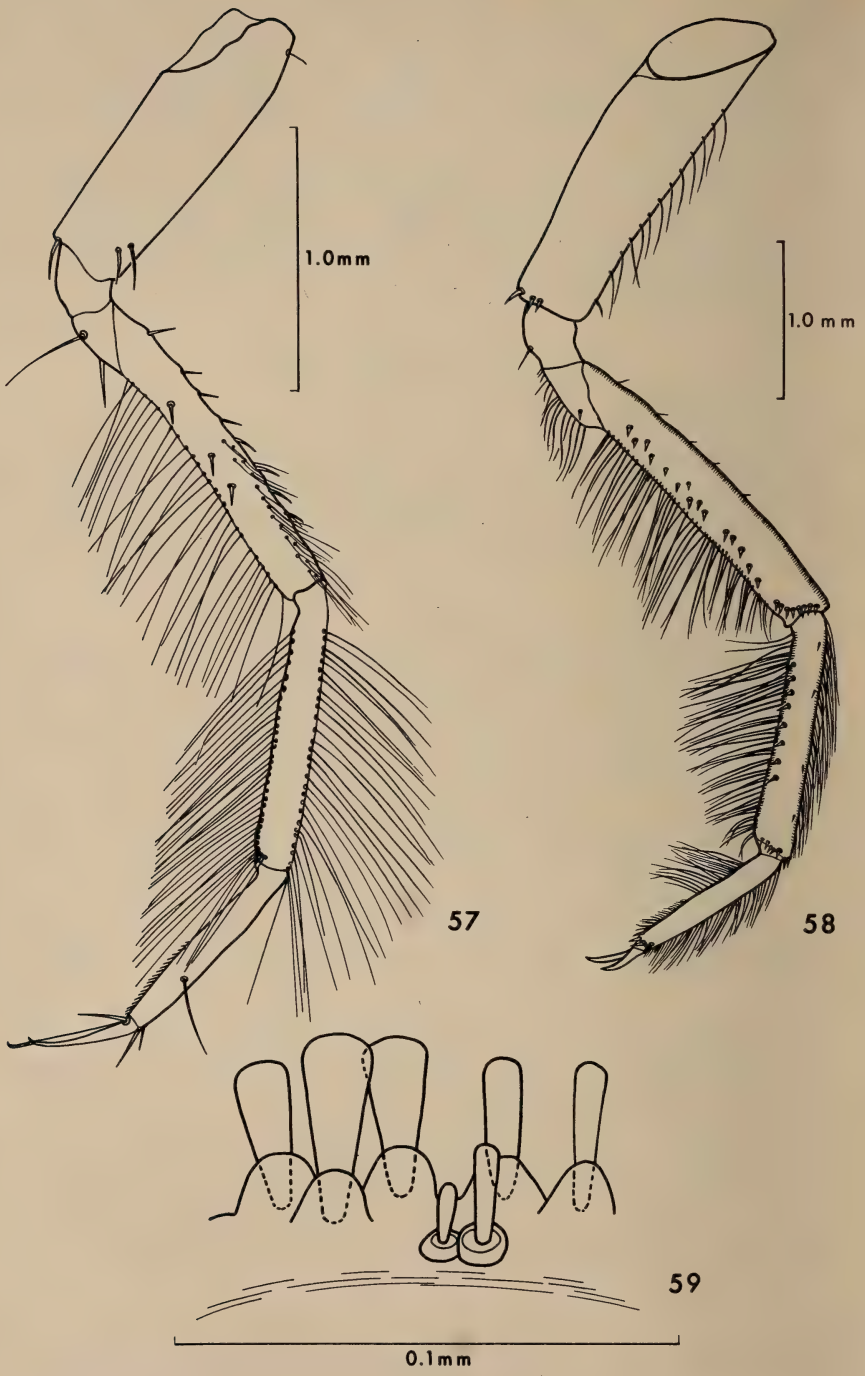
Apical segment of abdomen completely sclerotized, more than twice as long as the penultimate, but less than twice as long as cerci; apical segment and cerci fringed laterally with natatory setae.

Mean length (5) 12.82 mm (11.67 — 14.41); head width 1.95 mm (1.90 — 2.01); head length 2.15 mm (2.11 — 2.23).

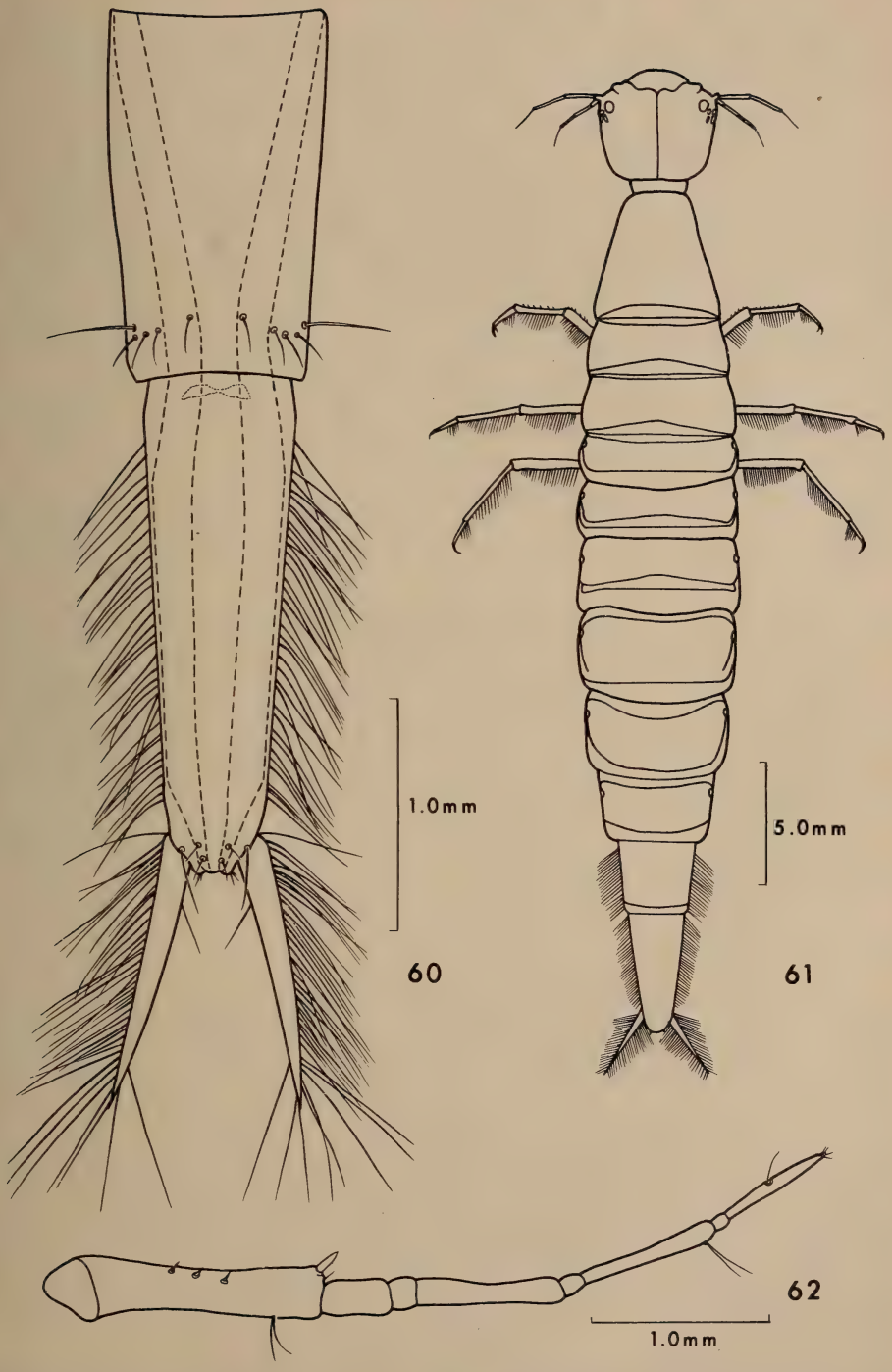
Second Instar

Structures common to the third instar are present in this stage. There is an added pair of abdominal spiracles on segment VII as well as a fringe of long natatory hairs on each side; similar fringes occur on the margins of the tarsus.

Mean length 24.29±1.97 mm; head width 3.10±0.09 mm; head length 3.64±0.15 mm.



FIGURES 57-59. *Dytiscus fasciventris*. First instar: 57, right front leg; third instar: 58, right front leg, posterior view; 59, clypeal setae in first instar.



FIGURES 60-62. *Dytiscus fasciventris.* First instar: 60, terminal segments and cerci; third instar: 61, larva; 62, right maxilla.

Third Instar (Figures 58, 61 to 66)

Head, excepting neck, subquadrate (Figure 64), less depressed than in the first instar. Fronto-clypeal plate broadly triangular, clypeus strongly arcuate, fringed with numerous clavate setae as long as 0.1 mm; epicranial suture less than two-thirds as long as head. Ocular area with three pairs of black ocelli; ocelli of the mid-lateral pair separated by their own length from each other, others close together. Rudimentary visual organ pale, situated in front of the dorsal ocelli and equal in diameter to the length of one. Antenna filiform (Figure 66) with seven segments; segment III almost as broad as long, segment IV sub-equal in length to VI. Mandible (Figure 63) elongate and falcate, four times longer than wide at base; lower lamella fringed with minute setae almost to apex. Maxilla linear (Figure 62), eight-segmented beyong the cardo; stipes elongate, five times as long as wide; segment I of palp as long as galea, apical segment eight times longer than penultimate. Labium without a ligula (Figure 65), base wider than long (7:3); palp four-segmented, segment II twice as long as IV.

Body fusiform, widest at the base of the abdomen; all segments membranous ventrally excepting last two. Pairs of spiracles present on mesothorax, laterally on abdominal tergites I to VII, and dorsally on VIII.

Pronotum 2¼ times longer than mesonotum, the latter shorter than metanotum (8:9). Coxa of front leg (Figure 58) sub-equal to femur in length and trochanter sub-equal to tarsus. Tarsi on all legs with two lateral fringes of natatory hairs.

Segment VII of abdomen three-fifths as long as VIII and as long as the cerci; natatory hairs present on segments VII and VIII.

Pronotum with an anterior double row and a single row of fine, body setae; single rows of setae occur near the posterior margins of succeeding segments as far as abdominal segment VI. Lateral setae in these rows were from 0.54 to 0.87 mm long, ventral setae from 0.59 to 1.00 mm; dorsal setae were shorter than these. Strong setae were well dispersed over tergites VII and particularly on VIII; venter of VIII covered uniformly with short spines.

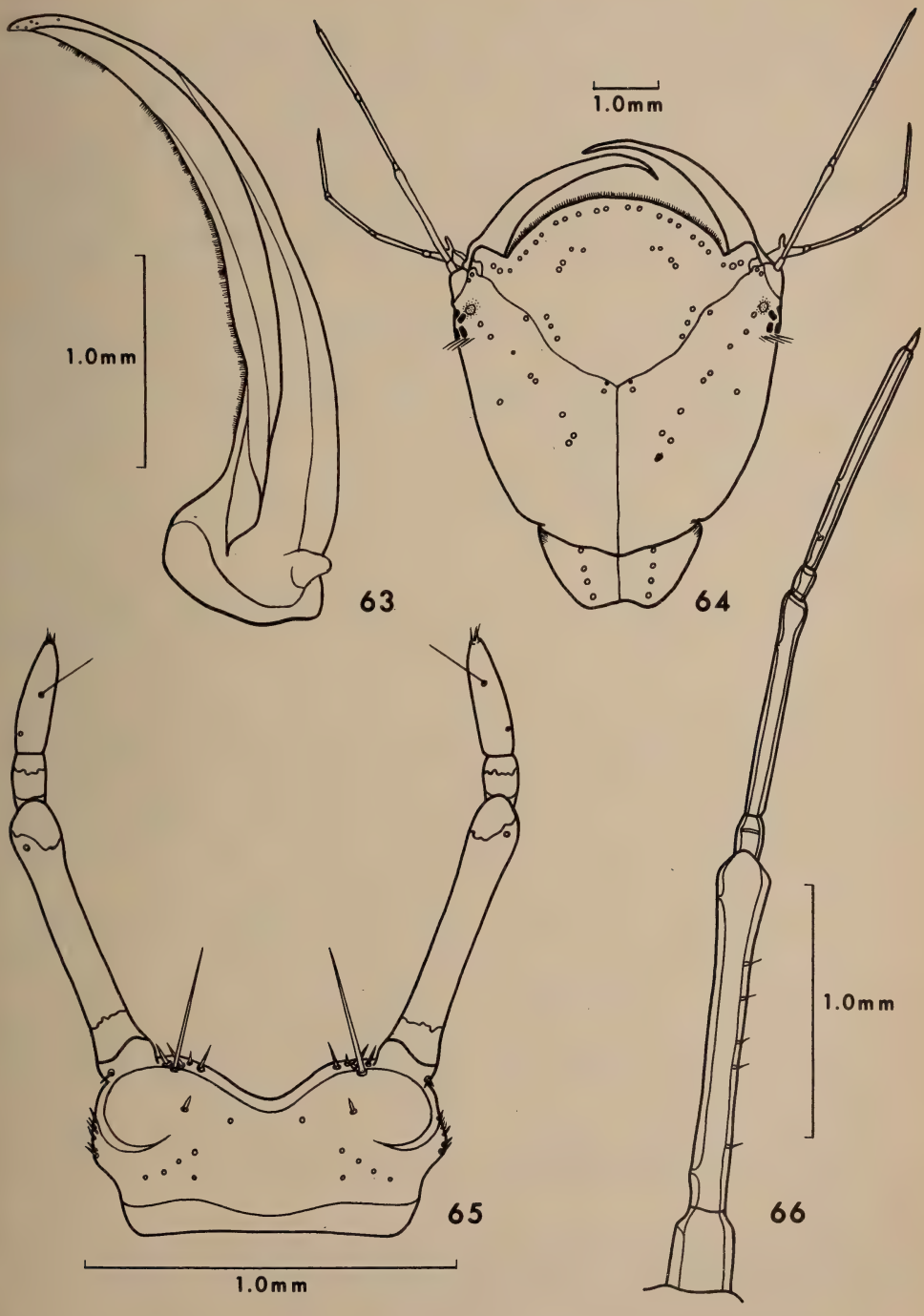
Mean length (15) 41.23±3.91 mm; head width 4.82± 0.25 mm; head length 5.68±0.23 mm.

Pupa (Figures 67, 84)

White. Sub-ovate, widest at the second abdominal segment. Apical segment three-quarters as long as the penultimate in ♀, sub-equal in ♂. Cercus bowed, about as long as the apical segment. Hind legs, when adpressed to the abdomen, meeting posterior margin of segment VII. Spiracles evident on abdominal segments I to VI.

Long setae or styli present, each arising on one side of a conical base ending in a strong spine. Principal styli as follows: Head, with 25 in clypeal region. Pronotum, with frontal crest of 60 to 70, and separated styli continued around the margins; also a central group of 8 or 9, and an arcuate band near the posterior border. Meso- and metanotum each with 6 or 7 on each side. Abdomen dorsally with increasing numbers on succeeding segments, totalling 50 or more on the apical; three near each spiracle and two at the lateral margin. Ventral styli on segment VII, three and on VIII, one, some 1.5 mm long. Cerci with styli on all sides.

Mean length (12) 27.02±0.91 mm; maximum width 11.34±0.56 mm; head width 5.85±0.38 mm.



FIGURES 63-66. *Dytiscus fasciventris*. Third instar: 63, right mandible; 64, head; 65, labium, ventral view; 66, right antenna.

Habits and Life History

Eggs of *D. fasciventris* were found at Chatterton on April 22 inserted between the leaf surfaces of *Scirpus cyperinus* (L.) Kunth (Figure 81) growing in a temporary pool. Additional eggs, spaced about 5.0 mm apart, were collected on the same species of sedge on May 30. The eggs hatched in 8 to 13 days in water at 14°C.

In the laboratory, first-instar larvae seized small larvae of *Aedes aegypti* and withdrew their body contents in about nine minutes, but appeared unable to capture small *Daphnia.* Large *Daphnia* were sometimes seized by third-instar larvae, but were rejected. At 23°C first-instar larvae completed their growth in three days, the second instar in seven. After this they remained as third-instar larvae for 20 days.

Mature larvae about to pupate were collected in damp soil near the margins of pools from June 14 to July 9. They occurred on or just below the surface under wet debris and often near moss. Each larva was reared in a large Stender dish with soil from the original habitat and covered with a greenhouse saucer. The larvae formed short oval earthen cells that averaged 2.7 cm in length and 2.4 cm in diameter on the inside. There appeared to be a prepupal interval of 3 to 7 days. After larval ecdysis the pupa lay on its back in the cell, supported by the dorsal styli and without close contact with the soil beneath. Larvae pupated from June 13 to July 9 (males), and from June 25 to July 9 (females), pupation requiring 7 to 11 days.

Larval development in the pools was spread over about nine weeks. First-instar larvae were collected from April 27 to May 8; second-instar from May 3 to May 24 and third-instar from May 9 to July 4. The large number of third-instar larvae intercepted by aquatic traps indicated that they were active swimmers in this stage.

Pupae were collected mainly from the large pool sites from June 18 to July 4. The pupal cells were usually located near the highest flood levels, and from 0.5 to 3.0 metres from the observed water line. The almost spherical cells appeared excavated in light soil just below the leafy humus. They were not as well constructed as those of *Acilius semisulcatus* as the roof of the cell often collapsed when the overlying leaves were removed. In one instance a cell uncovered on July 12 contained a teneral male.

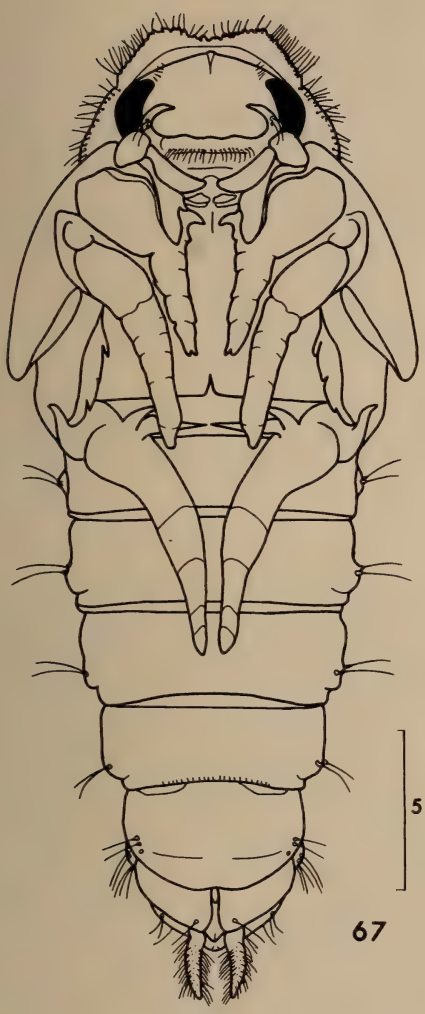
The species is univoltine. Some of the adults spend the winter in permanent water, but migrate to their breeding pools in early spring. Adults were collected in permanent pools from March 28 to April 14 and again from June 18 until the end of August. They were found in vernal pools from April 8 to July 9.

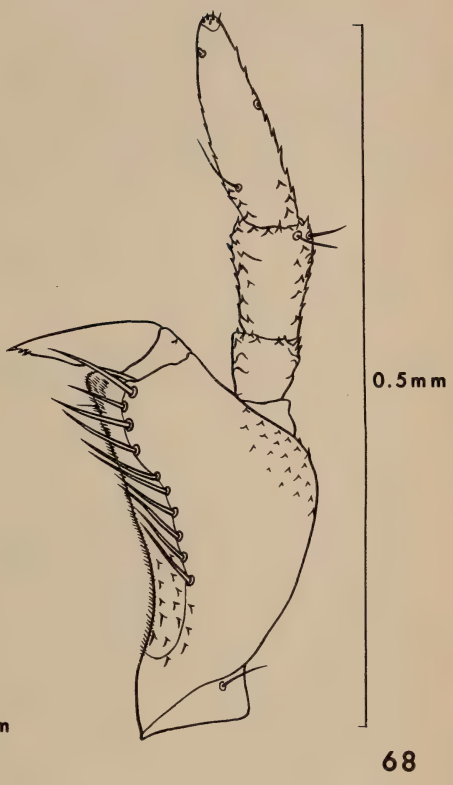
Mating pairs were observed in early April in water at 9 to 12°C. The examination of crop and gut contents showed that adults fed on various aquatic insects such as gerrids and the larvae of caddis flies and tabanids. During May, however, aedine larvae and pupae were vulnerable to larvae of this predator (James, 1961, 1966).

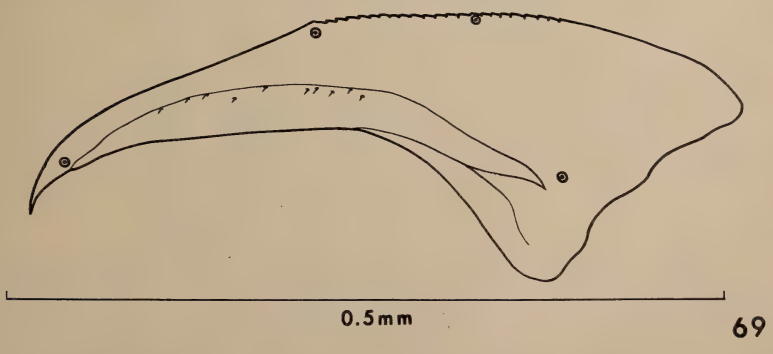
D. fasciventris is not abundant. Area samples taken in vernal pools during May indicated a mean population of 0.09 per square meter.

Parasites

Five of 20 pupae collected from June 18 to June 25 were found to be parasitized by larvae of an ichneumonid, *Medophron dytiscivorus* Mason (Mason, 1968). The same species was encountered in a later year in pupae from the same site. From 1 to 21 parasites (mean 8.8) were present on each pupa. The smaller ones appeared to feed inside the host, but soon developed into large larvae (Figure 87) that killed and almost completely devoured it.







FIGURES 67-69. *Dytiscus fasciventris*. 67, pupa. *Acilius semisulcatus*. First instar: 68, right maxilla; 69, right mandible.

The yellowish white, hymenopteriform larvae consisted of a head and 13 body segments. Preserved, mature larvae were about 10.1 mm long, with a head width of 0.95 mm; smaller larvae had head widths of 0.73 and 0.53 mm.

Larvae from one pupa formed cocoons over a period of three days through a spin-up required less than one. The cocoon (Figure 88) was brown, broadly fusiform and rounded at each end. Its silk was compactly woven into a lustrous, parchment-like covering equal to one-third the diameter of the cocoon. The mean length and greatest diameter of eight specimens were 8.3 and 3.4 mm.

In addition to *M. dytiscivorus,* a dead pupa and larva of the same host were found to be infested with larvae of an anthomyiid, *Paraprosalpia dytisci* Chillcott (Chillcott and James, 1966).

Acilius semisulcatus Aubé 1838

Egg (Figures 71 and 80)

Elongate-oval, somewhat broader toward the anterior end; pale yellow, with a thin membranous chorion. Mean length (10) 2.42±0.18 mm; greatest diameter 0.64±0.02 mm.

First Instar (Figures 68 to 70, 72 to 75)

Head trapezoidal, elongate and depressed, longer than wide (Figure 73). Fronto-clypeal plate triangular, with a spined tubercle on each side; epicranial suture almost half as long as head; margin of clypeus arcuate, with several rows of elongate, clavate setae. Ocular area with six ocelli: a long-stemmed large pair completely visible from above, behind these a small lateral pair; and in front and below, two separated ocelli, one latero-ventral, the other ventral. Rudimentary visual organ elongate, adjacent to the posterior dorsal ocellus. Antenna (Figure 72) four-segmented, robust, as long as the mandible; segment III three times as long as IV. Mandible falcate, 2½ times as long as wide at base. Maxilla (Figure 68) widest near the palpiger; palp three-segmented, with segment II half as long as III; dorsal margin of stipes with a row of 9 or 10 stout, curving spines; lower margin fringed with short setae. Labium (Figure 75) with a two-segmented palp based on a palpiger; base as long as wide, rounded apically and covered dorsally with numerous short spines; ligula present, divided apically by a median cleft.

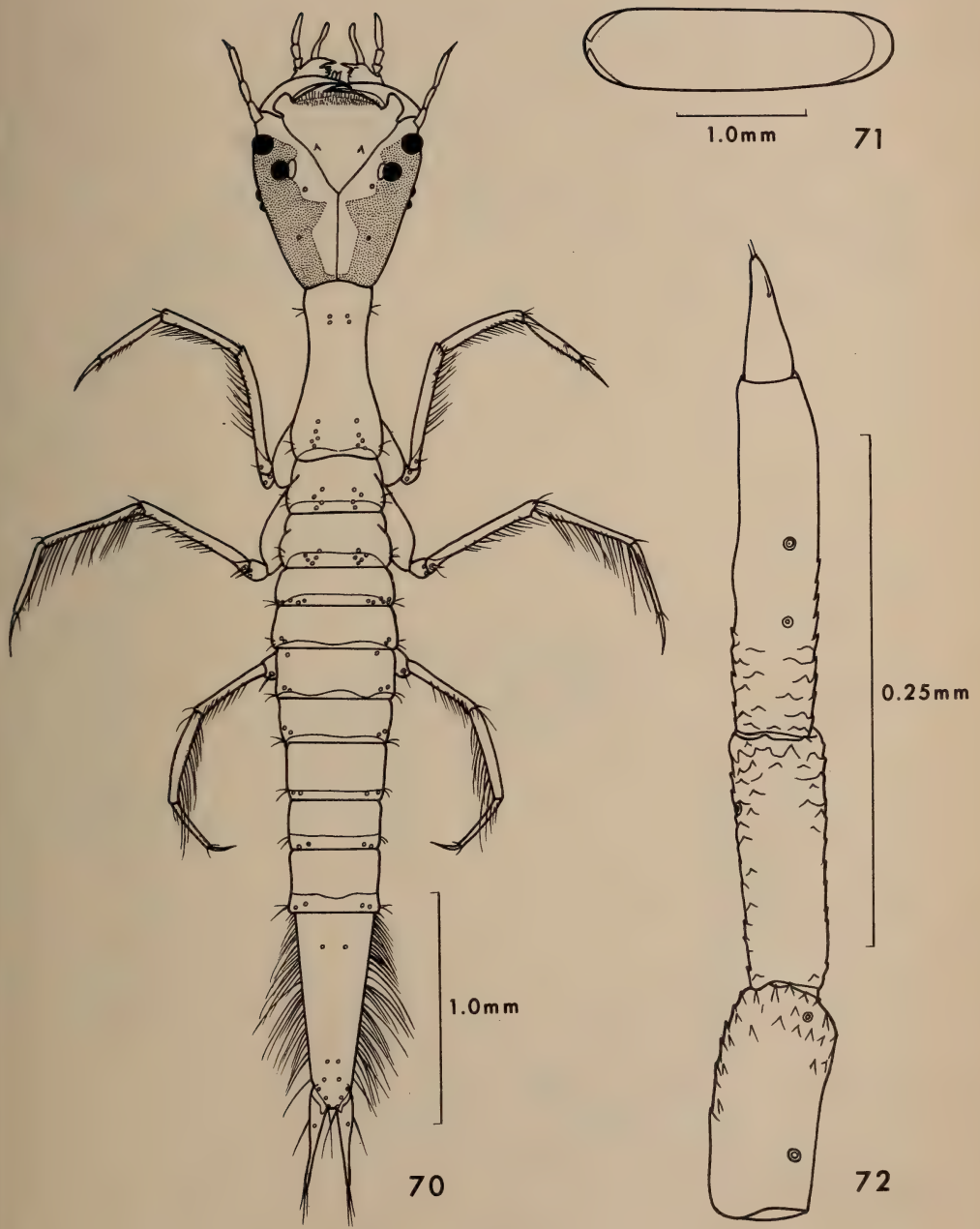
Body fusiform, widest near the base of the abdomen (Figure 70). Apical segment of abdomen slightly more than three times as long as the penultimate and twice as long as the cerci; also entirely sclerotized, fringed with lateral setae, and having a pair of terminal spiracular openings.

Femur and tibia with two rows of natatory hairs.

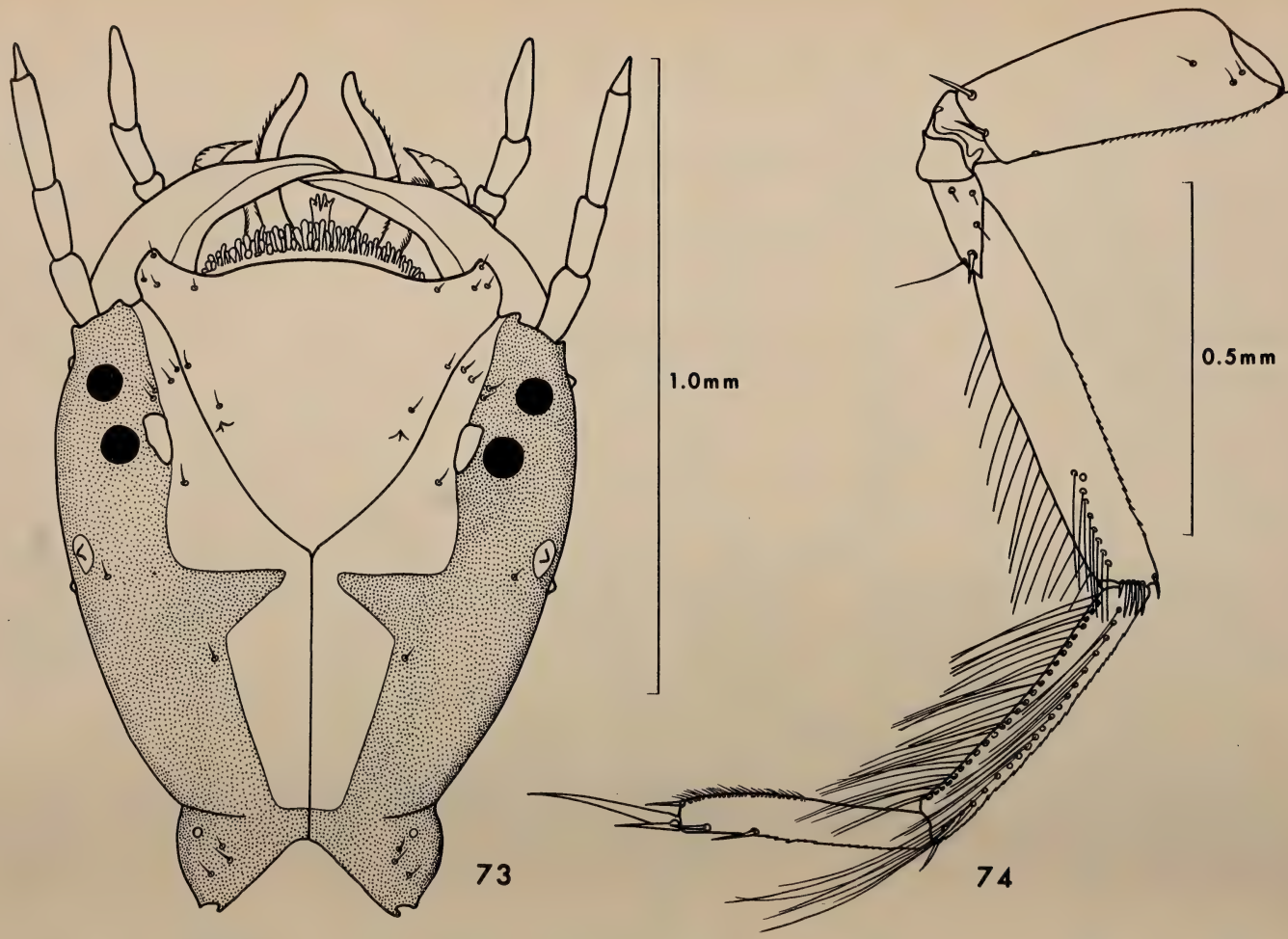
Mean length of larva shortly after eclosion 6.25 mm (5.19 — 7.62); head width 0.90 mm (0.81 — 0.98); head length 1.19 mm (1.11 — 1.27). Mean length of field-collected larvae (15) 9.47±1.52 mm; head width 1.0±0.03 mm; head length 1.31±0.05 mm.

Second Instar

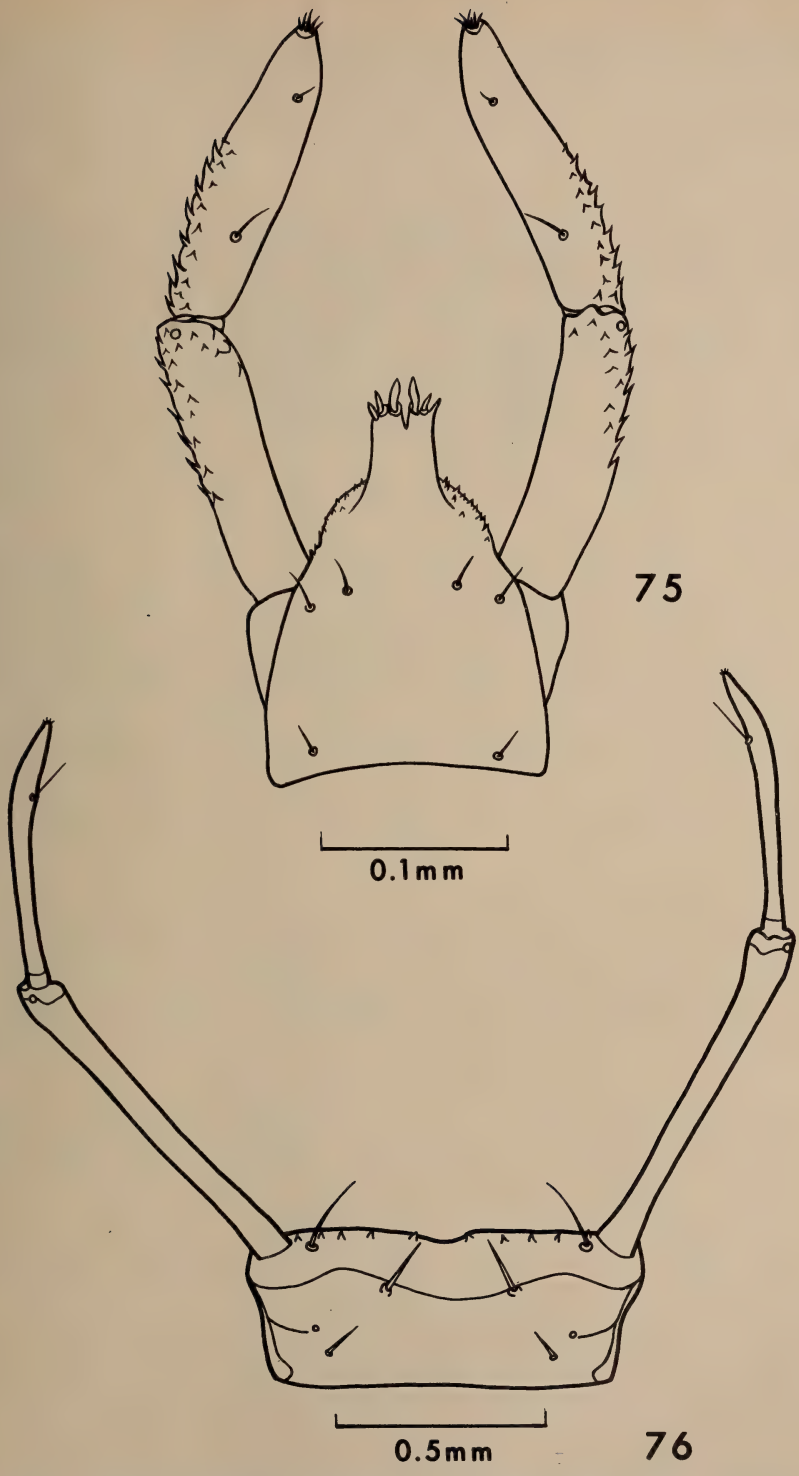
This stage marks the disappearance of the frontal tubercles from the head, but the presence of about 11 temporal spines as well as 5 or 6 strong spines on the ventral side near the neck. Lateral natatory hairs are found on the penultimate segment which is now fully sclerotized. Additional swimming hairs also occur on both sides of the tarsus. In young larvae incipient spiracles may be present on the penultimate segment, although their connection with the tracheal trunk is obscure.



FIGURES 70-72. *Acilius semisulcatus*. 70, first-instar larva, dorsal view; 71, egg; 72, first instar, right antenna.



FIGURES 73-74. *Acilius semisulcatus*. First instar: 73, head; 74, right front leg, anterior view.



FIGURES 75-76. *Acilius semisulcatus*. First instar: 75, labium, ventral view. *Colymbetes sculptilis*. Third instar: 76, labium, ventral view.

Toward the end of this stage, there is a pair of spiracles in the mesothorax, and the sites of future abdominal spiracles are evident on segments I to VII.

Mean length (17) 14.13±2.93 mm; head width 1.49±0.02 mm; head length 1.96±0.05 mm.

Third Instar

This stage was described by Wilson (1923). The appendages of the head are fully developed and the antenna, for example, is six-segmented by the addition of two subsegments. Specimens from Chatterton show the maxilla to be three times as long as wide and segment I of the palp one-third as long as the apical. In the labium, the cleft of the ligula equals one-half its length. Also, the prothoracic tergite is sub-equal in length to that of the apical abdominal segment excluding cerci.

Mean length (33) 22.53±1.62 mm; head width 2.06±0.07 mm; head length 2.75±0.10 mm.

Pupa (Figure 77)

White, except for the eyes. Sub-ovate. Head with three series of styli on each side of the frons. Pronotum with a frontal crest of 45 to 50 styli; also on each side are six lateral, three posterior (near the midline), and a group of 10 at the postero-lateral angles. Other dorsal styli are grouped along the rear margin of each segment near the midline as follows: mesonotum 4 to 6; metanotum 6 to 8. Abdominal tergite I, 8 or 9; II, 8 or 9; III, 7; IV, 7 or 8; V, 5 to 7; VI, 5 or 6; VII, 6; VIII, 3 or 4. Cercus with one dorsal and one lateral. Most of the styli on the abdomen are strongly spinulose. Cercus sub-equal in length to the apical segment.

Mean length 13.15 mm; greatest diameter 6.12 mm; head width 3.07 mm.

Habits and Life History

No eggs could be found on aquatic plants or elsewhere in the pools, but in the laboratory females laid eggs from April 13 to May 27. These were deposited on prostrate sedge leaves, though more often in batches of from 23 to 48 on the bottom of rearing containers. The eggs hatched in six days after incubation at 21°C. Some partially developed eggs were infected by a fungus, however, and did not hatch.

First-instar larvae were cannibalistic when reared in groups of five though supplied daily with 35 early-instar mosquito larvae. Prey put into the rearing container were seized within 2 to 3 minutes and their body contents soon removed. The predators moulted into the second instar after three days and into the third after an average of 10, though some unsuccessfully.

Mature larvae that would no longer feed were transferred to deep petri dishes containing water as well as moist soil for pupation. In one instance, a larva was seen to leave the water and crawl over the soil in a restless manner. Fifteen minutes later it began to construct a pupal cell in a depression beside the inside rim of the dish. At one stage the roof of the cell was almost completed before the side walls. The larva was observed to pick up bits of soil and large sand grains with its mandibles and put them into place overhead. In so doing, the head and thorax were directed repeatedly in a wide arc from the bottom to the roof while it balanced on its legs and abdomen. The larva worked almost continuously so that the outside of the cell was finished in 2¼ hours. The glass wall was the last to be lined with soil.

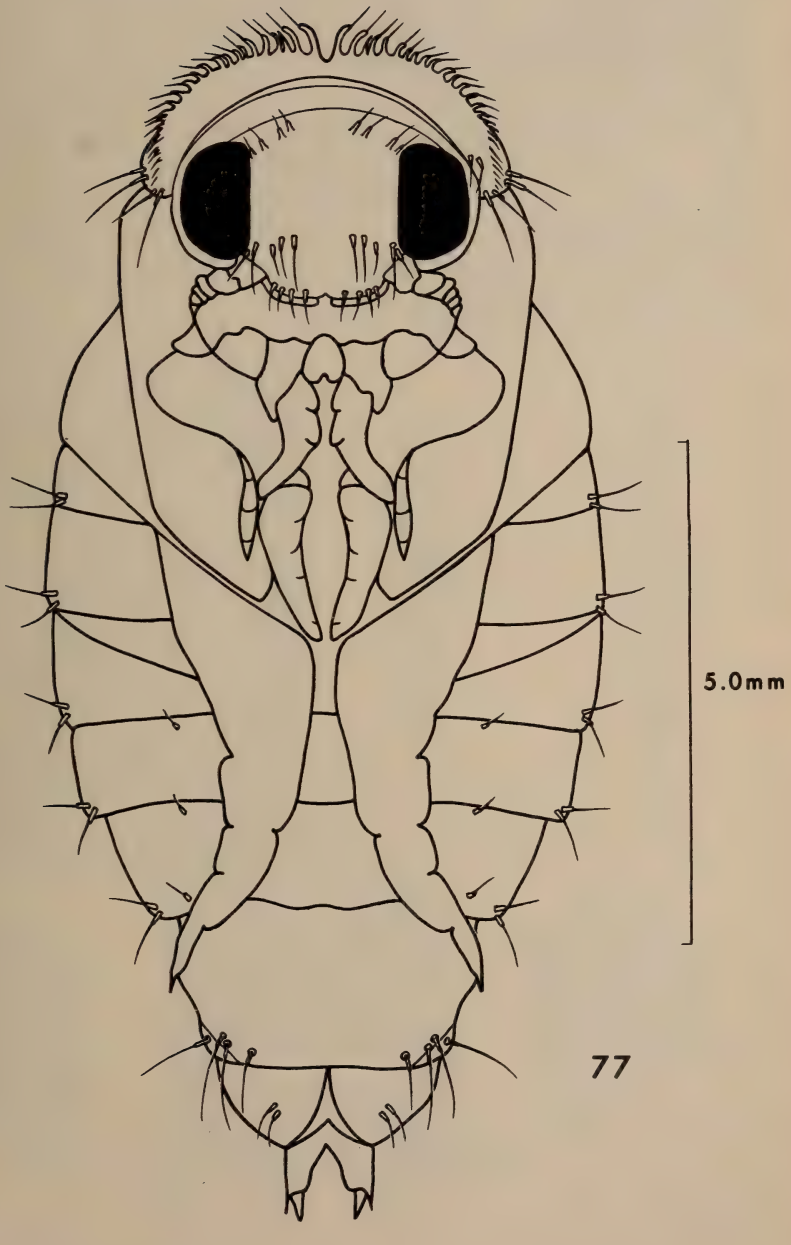
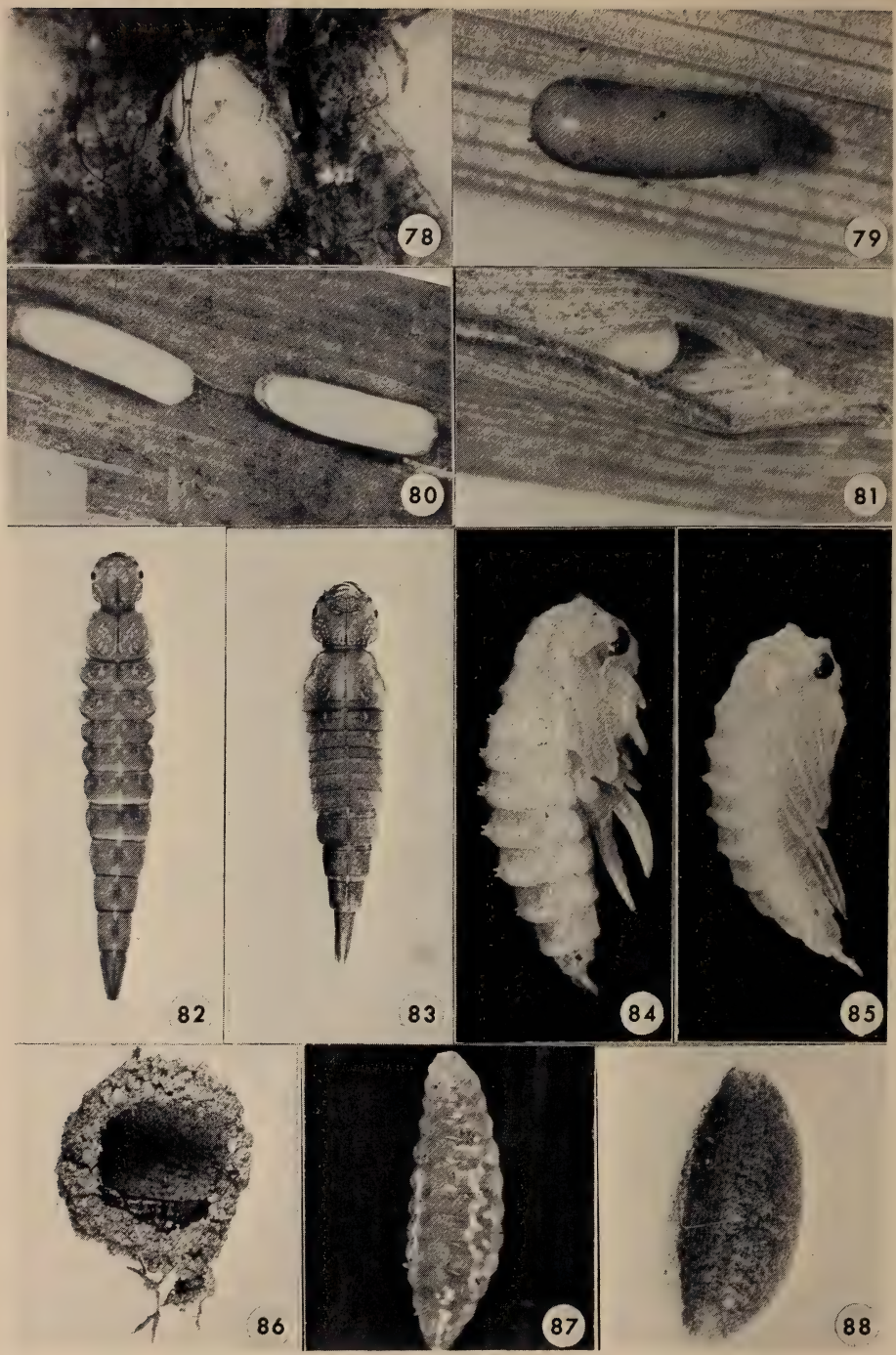


FIGURE 77. *Acilius semisulcatus*. Pupa, ventral view.



FIGURES 78-88. Dytiscid eggs 78-81: 78, *Agabus erichsoni;* 79, *Rhantus binotatus;* 80, *Acilius semisulcatus;* 81, *Dytiscus fasciventris.* 82, head and torso of *Agabus erichsoni,* third instar; 83, head and torso of *Colymbetes sculptilis,* third instar; 84, pupa of *Dytiscus fasciventris;* 85, pupa of *Agabus erichsoni;* 86, *Acilius semisulcatus:* section of pupal cell with larval exuvia; 87, fully grown larva of *Medophron dytiscivorus;* 88, cocoon of *M. dytiscivorus.*

The completed cell was broadly ovate, about 2.0 cm long and 1.5 cm in diameter. In this as in other pupal cells the last larval exuviae were found pushed to one side (Figure 86) and the pupa lying with its back to the bottom.

There is one generation a year. Adults were collected as early as April 1 but were not generally active until mid-April when mean pool temperatures had reached 9°C. Pairs were observed mating at the surface, often in bright sunlight, away from the margins and at water temperatures of from 12° to 18°C. In contrast to other water beetles, both adults and larvae were more active during daylight hours than at night (James, 1967).

Eggs were laid over a long period as evidenced by the wide overlapping of larval stages. First-instar larvae were collected from May 3 until June 2, second-instar from May 14 to June 3, and third-instar from May 14 to June 27, an overall period of 55 days. Third-instar larvae as well as pupae were also collected from June 18 to June 24 above the water line. They occurred near high flood levels, close to perennial vegetation and under moist humus.

Mature larvae collected in the pools but later reared in the laboratory pupated from June 16 to July 3, pupation lasting 8 to 13 days.

After emergence adults enter nearby pools but when these dry up move to more permanent water. According to Popham (1952) adults of *Acilius sulcatus* (L.), a European species, migrated from drying pools when high populations, including other aquatic insects, reached a critical level, and during midday. At Chatterton, many adults overwinter in permanent ponds, but move to vernal breeding pools in spring. These provide a variety of prey. Large populations of mosquito larvae and pupae are exposed to the predator during a large part of their development. The voracious adults and larvae also prey on other aquatic insects, especially after the remaining mosquitoes have emerged from the pools.

Key to Adults

Adults of various species of water beetles were repeatedly collected or observed during research in vernal pool communities in Hastings County, Ontario. Besides those that reproduce in this habitat, there were many less common as well as smaller forms, e.g. Hydroporinae, whose immatures have been little studied. Other species appeared to be seasonal or casual emigrants that undergo development in different waters.

The key below is offered to aid in their identification. The arrangement of families, sub-families and genera is largely that of Leech and Chandler (1956). However, in the separation of species I have drawn upon papers by Fall (1922), Hatch (1953), Leech (1939), and Wallis (1939), aided by specimens determined by specialists and now in the reference collection of the Research Institute, Belleville.

1. Antenna filiform or nearly so; first abdominal sternite completely divided by hind coxal cavities; hind coxae immovably united to metathorax 2

   Antenna club-shaped; first abdominal sternite extending for entire breadth posterior to hind coxal cavities; hind coxae not immovably united to metathorax ..... **Hydrophilidae** 37

2. Eyes divided by sides of head, appearing as a dorsal and ventral pair; antenna short, third segment enlarged; tarsi folded fanwise ..... **Gyrinidae** 36

   Eyes normal; antenna elongate and slender; tarsi not folded fanwise 3

3. Hind coxae expanded into large plates covering first two or three abdominal sternites and bases of hind femora ..... **Haliplidae** 4

Hind coxae not expanded into large plates, not covering hind femora, nor more than first abdominal sternite ..... **Dytiscidae** 5

Haliplidae

4. Pronotum with the longitudinal basal plica less than one-quarter the length, measured from the base of the plica to the anterior margin; head dorsally with a pair of small, dark markings between the eyes and a larger U-shaped spot posteriorly ..... *Haliplus immaculicollis* Harr.

Pronotum with the longitudinal basal plica more than one-quarter the length; head dorsally without dark pigment between and behind the eyes ..... *Haliplus longulus* Lec.

Dytiscidae

5. Middle of prosternum and its postcoxal process in the same plane; front and and middle tarsi five-segmented 16

Middle of prosternum not in the same plane as its postcoxal process; front and middle tarsi four-segmented 6

6. Hind coxal processes without lateral lobes; bases of hind trochanters entirely free; small, approximately 1.0 mm long ..... *Bidessus affinis* (Say)

Hind coxal processes with lateral lobes which cover bases of hind trochanters; more than 3.0 mm long 7

7. Epipleura with a diagonal carina crossing near base; front and middle tarsi four-segmented ..... *Hygrotus* Stephens 8

Epipleura without a diagonal carina crossing near base; front and middle tarsi five-segmented, the fourth very small ..... *Hydroporus* Clairville 11

8. Length 4.2 mm or less; elytral markings never distinctly vittate 9

Length 4.4 to 5.0 mm; pale vittate markings toward base of elytra in males; elytra of females dark without vittate markings ..... *Hygrotus impressopunctatus* (Schall.)

9. Head with front margined anteriorly; body broadly oval; elytra strongly punctate ..... *Hygrotus sayi* B. B.

Front not margined; body depressed; elytra not strongly punctate 10

10. Elytra moderately punctate; sternum mostly black; anterior and posterior margins of pronotum lined with black ..... *Hygrotus turbidus* Lec.

Elytra feebly punctate; sternum rufous; anterior and posterior margins of pronotum not black ..... *Hygrotus laccophilinus* Lec.

11. Metacoxal process conjointly, obtusely angulate behind; deeply bisinuate; sternites rufous ..... *Hydroporus undulatus* Say

Metacoxal process conjointly truncate behind; not deeply bisinuate; sternites partly black 12

12. Anterior claw of front tarsus of male acutely toothed; meso- and metasternum black, remainder of abdomen rufopiceous ..... *Hydroporus dentellus* Fall

Anterior claw not acutely toothed; black pigment on venter not restricted to the meso- and metasternum 13

13. Length 4.0-4.5 mm; apex of posterior coxal process squarely truncate at middle; head mainly piceous ..... *Hydroporus despectus* Shp.

Length 3.0 to 3.3 mm; apex of posterior coxal process angularly prominent at middle; head rufous ..... *Hydroporus fuscipennis* Schaum

14. Elytra with pale, oblique humeral and sub-humeral spots; length 3.4 to 4.0 mm ..... *Hydroporus signatus* Mann.

Elytra without oblique spots; length 2.9 to 3.2 mm 15

15. Anterior claw of male prostarsus thickened, the tip acuminate; head rufous, piceous between the eyes; elytra dark brown, paler near the base and along the margins ..... *Hydroporus striola* Gyll.

Anterior claw of male protarsus not thickened; head rufous; elytra reddish brown with the disk darker posteriorly ..... *Hydroporus tristis* (Payk)

16. Scutellum covered by margin of pronotum; hind tarsus with a single straight claw ..... *Laccophilus* Leach 17

Scutellum entirely visible; hind tarsus with two claws 18

17. Head, pronotum, front and middle legs yellowish; abdominal sternites rufous to dark brown; elytra dark brown, speckled, with four pale submarginal spots; length 5.2 to 5.5 mm ..... *Laccophilus maculosus* (Germ.)

Head, pronotum, front and middle legs brown; abdominal sternites black, reddish along apical margins; elytra not speckled and without submarginal spots; length 4.0 to 4.3 mm. ..... *Laccophilus biguttatus* Kby.

18. Eyes emarginate above bases of antennae; first three segments of front tarsi of male forming a widened plate with adhesion disks ..... **Colymbetinae** 19

Eyes not emarginate above bases of antennae; first three segments of front tarsi of male forming a round or oval plate with adhesion disks ..... **Dytiscinae** 34

19. Hind femora with a linear group of ciliae at the posterior apical angle 20

Hind femora without such a group of ciliae 30

20. Hind tarsal claws of equal length; if slightly unequal, then both are very short, only one-third the length of the fifth tarsal segment ..... *Agabus* Leach 21

Hind tarsal claws unequal in length; outer claw two-thirds or less of the inner ..... *Ilybius* Erichson 28

21. Length 8.5 to 11.7 mm 22

Length less than 8.5 mm. 23

22. Surface of elytra coarsely reticulate; process of prosternum rounded; anterior claw of male protarsus expanded at base; length 10.3 to 11.7 mm ..... *Agabus erichsoni* G. and H.

Elytra finely reticulate; process of prosternum acutely carinate; claws of male protarsus of equal width at base; length 8.5 to 9.2 mm ..... *Agabus confinis* Gyll.

23. Pronotum with wide side margins; anterior claw of male protarsus with a large sub-median tooth ..... *Agabus sharpi* Fall

Pronotum with side margins of normal width; anterior claw of male protarsus without a tooth 24

24. Mesocoxae and metacoxal plates separated by a fourth or less the width of the latter measured along the same line; pronotum and elytra rugose, marked with short longitudinal strigae that become transverse on the apical half of the elytra ..... *Agabus bifarius* Kby.

Mesocoxae and metacoxal plates separated by more than a quarter the width of the latter; pronotum and elytra without longitudinal strigae 25

25. Male protarsi and mesotarsi with large circular adhesion disks beneath; elytra coarsely and irregularly reticulate, with a linear mark along the basal half of the side margin ..... *Agabus anthracinus* Mann.

Male protarsi and mesotarsi without circular adhesion disks; elytra finely reticulate, without a linear spot 26

26. Mesocoxae and metacoxal plates separated by more than half the width of the latter measured along the same line; male protarsal claws narrow, sinuate; pronotum black with side margins testaceous ..... *Agabus canadensis* Fall

Mesocoxae and metacoxal plates separated by less than half the width of the latter measured along the same line; male protarsal claws not narrow or sinuate; pronotum black with side margins rufous to black 27

27. Process of prosternum acutely carinate; margins and epipleurae of pronotum and elytra rufous; elytra black ..... *Agabus kenainsis* Fall

Process of prosternum convex; margins and epipleurae of pronotum rufous to black; elytra brown ..... *Agabus phaeopterus* Kby.

28. Length 9.5 mm or more; last sternite of male with an acute carina one-third as long as the segment; venter rufous ..... *Ilybius biguttulus* (Germ.)

Length less than 9.0 mm; last sternite of male without a carina or with a short one one-sixth as long as the segment; venter black 29

29. Last sternite of male with a short apical carina; protarsal claws sinuate; elytral reticulation coarse in female ..... *Ilybius ignarus* Lec.

Last sternite of male without a carina; protarsal claws not sinuate; elytral reticulation fine in female ..... *Ilybius discedens* Shp.

30. Anterior point of metasternum triangularly split to receive tip of the prosternal process; pronotum margined laterally 31

Anterior point of metasternum depressed, with a shallow pit or broad notch to receive the tip of the prosternal process; pronotum not margined 33

31. Head between and behind the eyes, black; metacoxal plates yellow to reddish brown; pronotum without a pair of dark spots 32

Head with a transverse yellow or rufous spot between the posterior margins of the eyes; metacoxal plates virtually all black; pronotum with a pair of dark spots ..... *Rhantus binotatus* (Harr.)

32. Pronotum of male with a median dark spot; apex of last abdominal sternite reddish brown, darker than base; elytra without a dark patch near the midline ..... *Rhantus notatus* (Fab.)

Pronotum of male normally without a median dark spot; apex of last abdominal sternite not darker than base; elytra with a pair of large, well-defined black patches near the midline, one-quarter the distance from the apex ..... *Rhantus tostus* Lec.

33. Elytra sculptured with numerous transverse grooves; front of head and sides of pronotum light brown ..... *Colymbetes sculptilis* Harr.

Elytra without transverse grooves, coarsely reticulate; front of head, sides of pronotum and elytra reddish black ..... *Neoscutopterus angustus* Lec.

34. Posterior margins of first four hind tarsal segments with dense fringes of flat, golden cilia, length 12.0 to 15.0 mm 35

Posterior margins of first four hind tarsal segments bare; length 23.0 to 34.0 mm ..... *Dytiscus fasciventris* Say

35. Outer margin of metasternal side wings arcuate; outer (shorter) spur at apex of hind tibia blunt, emarginate; pronotum with two yellowish cross-bands; elytra fluted in female ..... *Acilius semisulcatus* Aubé

Outer margin of metasternal wings straight; outer spur at apex of hind tibia acute; pronotum with a single reddish band; elytra not fluted in female ..... *Hydaticus modestus* Shp.

Gyrinidae

36. Elytra covered with fine, short oblique striolae; length 7.1 to 7.6 mm ..... *Gyrinus affinis* Aubé

Elytra finely and sparsely punctulate; length 5.5 to 6.0 mm ..... *Gyrinus lecontei* Fall

Hydrophilidae

37. Meso- and metasterna with a continuous median keel which is prolonged into a spine between the hind coxae 38

Meso- and metasterna without a continuous median keel 39

38. Prosternum carinate; metasternal keel not or hardly reaching beyond bases of hind trochanters ..... *Hydrochara obtusata* (Say)

Prosternum sulcate to receive anterior end of mesosternal keel; metasternal keel projecting beyond hind trochanters as a spine 39

39. Basal quarter of hind femur pubescent, extending to tips of trochanters; two-thirds of anterior face of femur dark brown ..... *Tropisternus natator* d'Orch.

Basal third of hind femur pubescent, extending beyond tips of trochanters; basal half of anterior face of femur dark brown ..... *Tropisternus mixtus* (Lec.)

40. Head strongly deflexed; middle and hind tibiae fringed with long hairs ..... *Berosus* Leach

Head not strongly deflexed; middle and hind tibiae without long hairs 41

41. Larger species, length 6.0 mm or more 42

Smaller species, length 4.0 mm or less 43

42. Elytra striate, marked by at least 10 grooves; mesonotum with an acute median projection ..... *Hydrobius fuscipes* L.

Elytra not striate; mesonotum with a laminate median projection ..... *Enochrus cinctus* (Say)

43. Maxillary palpi robust, short, sub-equal in length to the antennae, apical segment longer than the penultimate ..... *Anacaena limbata* Fab.

Maxillary palpi elongate, one and one-half times as long as the antennae; apical segment shorter than penultimate ..... *Cymbiodyta* Bedel

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AN EXAMINATION OF POSSIBLE SIDE EFFECTS IN PEPPERS SIDE-DRESSED WITH DISULFOTON

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Abstract

Granular disulfoton applied as a side-dressing to plots of pepper plants at the rate of 2 pounds actual toxicant per acre had no effect on plant growth, yield, or the level of macro and micro elements in the leaves.

Introduction

A previous investigation showed that one annual side-dressing with a granular formulation of disulfoton provided effective control of the green peach aphid, *Myzus persicae* (Sulzer), on peppers in southwestern Ontario (Foott *et al,* 1969). Control extended throughout the entire period that aphids were most prevalent in pepper fields, but the fruits had no detectable residues of disulfoton or its oxidation products 42 days after treatment. Appreciable amounts of the insecticide or its oxidation products were present in the leaves 42, 50, and 60 days after treatment.

After completion of the above study, it was noted that many investigators had detected significant increases or decreases in plant growth and yield of various crops when pesticides were added to the soil. In some instances there were also changes in the macro and micro element levels in the plants. These observations were of special interest because the plant response could not be explained by differences in the degree of insect control. Although most of the investigations have involved systemic insecticides (Stanley and Qualset, 1968), side effects were also noted with soil-incorporated fungicides and nematocides (Cole *et al,* 1968a) and chlorinated hydrocarbon insecticides (Cole *et al,* 1968b).

A response to disulfoton has been reported for several crops, but there are no data for peppers. The possibility that side effects might occur in this crop was examined in 1968.

Materials and Methods

Pepper seedlings of two varieties, Vinedale and Staddon's Select, were transplanted to field plots on June 4. The field, which was classified as a sandy loam, had been in fallow in 1967. In the spring of 1968, manure was applied at 15 tons per acre and 5-20-20 fertilizer at 500 pounds per acre. A 10-52-17 formulation of starter solution was used in the planting water at a rate of 4 pounds per 45 gallons of water.

Three plots were side-dressed with a 10% granular formulation of disulfoton at a rate of 2 pounds actual toxicant per acre on June 14, which was prior to fruit formation, three plots were treated on July 15 when small fruits were present, and three plots were untreated. To offset the possible effect of early aphid damage on the late-treated plants, endosulfan at 0.5 pound actual toxicant per acre was applied to the foliage prior to July 15 whenever the infestation level reached three or more aphids per leaf. A fourth set of plots was treated with endosulfan only whenever aphid infestations reached three per leaf. Thus, if significant differences in plant response occurred between the endosulfan and disulfoton-treated plots, the differences would not be due to aphid injury, but presumably to side effects of disulfoton.

Five plants per plot were severed at ground level and their tops weighed on four separate dates in August. The remaining plants in each plot were used to ascertain yield by picking and weighing marketable fruits throughout the season. Leaf samples were taken from plants in each plot on July 15 and August 22 and analyzed for their mineral content by Dr. G. M. Ward, Research Station, Harrow, using methods described by Ward and Johnston (1962) and by atomic absorption techniques,

Adequate precipitation throughout the summer nullified the need for irrigation.

Results

No significant differences in fresh weights of plants occurred between treatments in the Vinedale variety (Table I). Significant differences between treatments did occur in Staddon's Select, but there was no evidence that either aphid injury or side effects of disulfoton were responsible.

No significant differences in yield of marketable peppers were obtained for either variety (Table II).

The leaf analyses, according to Dr. G. M. Ward, indicated that disulfoton had not influenced the macro and micro element levels in the leaves.

Discussion

Possible explanations for observed side effects with soil-incorporated chemicals include (1) control of detrimental soil microorganisms, (2) the release of plant nutrients by death of the soil microbial population, (3) utilization of organic phosphorus by the plant when organophosphorus compounds are used, and (4) the influence of organic phosphorus on enzymes and high energy bonds.

Hacskaylo and Ergle (1955) obtained increased growth of cotton plants with insecticides in sand culture experiments. Cole *et al* (1968a; 1968b) found that soil-incorporated pesticides affected the fresh weight and the macro and micro element levels of corn and bean plants in greenhouse experiments even though the pots and soil were steam treated prior to the addition of chemicals. The results of these investigations show that a soil microorganism-pesticide interaction is not essential to produce side effects. Stanley and Qualset (1968) noted that in most

TABLE I. Fresh weight of aerial parts of pepper plants under different treatment conditions

Variety	Treatment	Average fresh weight per plant (g)*
Vinedale	Side-dressed with disulfoton June 14	531.1 a
	Side-dressed with disulfoton July 15**	517.5 a
	Endosulfan whenever required for aphid control	444.9 a
	Check	443.6 a
Staddon's Select	Side-dressed with disulfoton June 14	716.1 a
	Side-dressed with disulfoton July 15**	511.9 b
	Endosulfan whenever required for aphid control	712.1 a
	Check	516.7 b

*Each figure is the mean of four replicates of five plants each. Treatments associated with the same letter were not significantly different at the 5% level (Duncan's multiple range test).

**Aphids controlled with endosulfan prior to July 15

TABLE II. Yield of marketable peppers under different treatment conditions

Variety	Treatment	Average yield (g) of marketable fruits per plant			
		Plots			
		I	II	III	Totals*
Vinedale	Side-dressed with disulfoton June 14	831.9	672.1	1,008.7	2,512.7
	Side-dressed with disulfoton July 15**	956.2	875.1	1,028.0	2,859.3
	Endosulfan whenever required for aphid control	889.5	671.0	695.0	2,255.5
	Check	859.0	651.4	915.5	2,425.9
Staddon's Select	Side-dressed with disulfoton June 14	1,191.4	1,063.2	1,657.5	3,912.1
	Side-dressed with disulfoton July 15**	1,539.5	1,281.9	1,621.1	4,442.5
	Endosulfan whenever required for aphid control	1,441.6	1,101.6	1,244.9	3,788.1
	Check	1,549.3	1,435.0	1,525.7	4,510.0

*There were no significant differences between treatments for either variety

**Aphids controlled with endosulfan prior to July 15

of the reported investigations they reviewed there appeared to be adequate phosphorus fertilization and doubted that the small amount of phosphorus in insecticides would affect plant growth. This was confirmed in the present investigation where the phosphorus levels were similar in treated and untreated plots. The possibility that the organic phosphorus in insecticides might have an influence on enzymes and high energy bonds has not been disproved. However, if the results reported by Stanley and Qualset (1968) are substantiated, the mechanism would account for both increased vegetative and reduced reproductive growth. Also, this latter explanation would not apply to non-phosphorus compounds.

This study shows that disulfoton does not influence the size, yield, or nutrient balance of field-grown pepper plants when adequate nutrients and moisture are available. It provides further evidence that more detailed research is required to determine the prerequisite conditions under which soil-incorporated pesticides can elicit side effects in plants. Only then can the mechanisms which might be responsible for a change in plant response be properly evaluated.

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NALED FOR CONTROL OF *TETRANYCHUS URTICAE* KOCH IN THE GREENHOUSE

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Abstract

In an experimental greenhouse compartment made as airtight as possible by sealing the connections between panes of glass, 100% of the active stages and over 90% of the quiescent stages of *Tetranychus urticae* Koch were killed when naled was vaporized from heating pipes. Commercial cucumber greenhouses are apparently not sufficiently airtight to confine the naled vapor and only active stages are killed.

Seven hours of continuous ventilation following an overnight treatment failed to remove all traces of naled from the compartment. This may explain the erratic behavior and occasional mortality of honeybees which are released in treated greenhouses after only a few hours of ventilation. To prevent possible harm to bees, growers should thoroughly ventilate their greenhouses the day after treatment and not release the bees until the second morning after treatment.

Introduction

Naled (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate) is vaporized from greenhouse heating pipes for control of aphids, thrips, greenhouse whitefly *(Trialeurodes vaporariorum* (Westwood)), and two-spotted spider mite (*Tetranychus urticae* Koch) on cucumbers. The vapor reaches all areas of the plants and should be superior to sprays and dusts for insect and mite control subsequent to the formation of a thick canopy of leaves at the top of the supporting wires.

Growers interviewed often expressed disappointment with the material's effectiveness against mites, and some suspected they had a resistant strain. They also stated that honeybees released in greenhouses after a naled treatment frequently failed to pollinate the blossoms and sometimes died. In these instances the bees had been removed or protected during fumigation and the greenhouses ventilated for several hours.

Reported herein are the results of tests conducted to examine (1) the efficacy of naled against all stages of *T. urticae,* and (2) the possibility that a portion of the toxic vapor remains in greenhouses subsequent to a normal period of ventilation.

Materials and Methods

All experiments were conducted in a greenhouse compartment which was 1605 cubic feet in size and had manually-operated vents at the top and on one end. The connections between panes of glass were sealed and cloth was wedged between the bottom of the entrance door and the floor to make the compartment as airtight as possible during fumigation.

The formulation of naled used in all experiments was a 4.8 emulsifiable concentrate (4.8 pounds active ingredient per gal) which was applied to cold heating pipes at the recommended rate of 2 fluid ounces per 10,000 cubic feet. The pipes were then heated to a minimum of 160°F. Treatments were made in the late afternoon and the compartment remained closed overnight.

The efficacy of naled against *T. urticae* was determined by conducting separate tests with (1) eggs in six different age groups, (2) all four active stages (larva,

protonymph, deutonymph and adult), and (3) the three quiescent stages which occur between active stages. Bush lima beans served as the host plant for propagation of the mites and in all experiments. One infested leaf comprised a replicate.

Leaves were examined prior to fumigation and all forms of the mite not in the specific stage to be treated on that date were removed. Subsequent to fumigation the host leaves were maintained in a rearing room until compilation of mortality data was completed. When quiescent stages and eggs near eclosion were involved, it was necessary to re-examine the leaves immediately after their removal from the treated compartment to remove active stages which emerged and died during the night.

Two series of replicates were used in tests with the active and quiescent forms. In one, the mites were located on the lower surface of leaves *in situ,* which is the natural environment for *T. urticae.* Leaf petioles were ringed with tanglefoot to prevent active forms from crawling off the plant. In the second, the mites were on detached leaves ringed with tanglefoot and placed with the lower surface uppermost on pads of moist absorbent cotton in petri dishes. This method permitted greater ease in the examination of infested leaves under a microscope. Tests with eggs were confined to the second method.

The possibility that toxic vapors remained in the compartment subsequent to ventilation was examined by infesting bean leaves with adult females of *T. urticae* after four and seven hours of continuous ventilation and assessing mite mortality 24 hours later. Some of the leaves to be infested were in the compartment during the fumigation and ventilation periods, whereas others were not introduced until completion of the ventilation period. This was to determine if a toxic residue occurred on the foliage or was confined to the air. In additional tests, the compartment was ventilated for four or seven hours the day after fumigation, but the leaves were not populated with mites until the following morning.

Results

As an ovicide, naled was only effective against eggs which were within a few hours of eclosion. Usually these eggs did not hatch and the dead, reddish embryo could be observed inside the transparent chorion. When eggs did hatch the larvae died at or shortly after eclosion.

There was 100% mortality of all four active stages in every test conducted. An average mortality of 99.1% occurred on 59 infested leaves even when the dosage was lowered to two-thirds the recommended rate.

The average mortality for 42 replicates when quiescent stages were treated was over 90% (Table I). The majority died in the quiescent stage, but a few succumbed soon after development into the succeeding active form. Since the effect of naled was similar for all three quiescent stages, mortality data were combined in the above table.

Table II shows the results of experiments conducted to determine if toxic vapors persisted in the greenhouse subsequent to four and seven hours of continuous ventilation. Adult mortality was high in both instances. Because the number of mites which left leaves *in situ* was much higher when the compartment had been fumigated than when untreated, it is probable that most of these mites had been seriously affected by naled fumes and that the true mortality in a recently fumigated compartment was greater than indicated in the table. The similarity in mortality of mites on leaves which had been exposed to naled and on leaves which had not been exposed showed that no residue remained on the foliage.

TABLE I. Efficacy of naled against quiescent stages of *T. urticae*

	Location of quiescent stages during treatment	No. of replicates*	Average no. of forms per replicate	% Mortality In quiescent stage	% Mortality In subsequent active stage	% Mortality Total
Treated	On lower surface of leaf *in situ* on plant (A)	21	40.4	80.7	11.4	92.1
	On detached leaf on pad of moist absorbent cotton in petri dish (B)	21	64.5	85.9	10.1	96.0
Control	(A)	18	199.6	0.4	0.2	0.6
	(B)	18	167.8	0.7	0.4	1.1

*A replicate comprised one leaf populated with 20 adult females

TABLE II. Mortality of adult famales of *T. urticae* placed on plants subsequent to treatment of a greenhouse compartment with naled and a ventilation period of four or seven hours

Ventilation period (hours)	Location of mites during tests	No. of replicates*	Average no. mites alive per replicate	Average no. mites dead per replicate	No. mites in tanglefoot**	No. mites which left plant
(1) *Plants to be infested were in compartment during fumigation and ventilation periods*						
4	On lower surface of leaf *in situ* on plant (A)	25	0.76	11.24	0.20	7.80
	On detached leaf on pad of moist absorbent cotton in petri dish (B)	21	1.91	13.57	4.52	0
7	(A)	18	0.11	13.39	0.22	6.28
	(B)	18	2.11	15.28	2.61	0
(2) *Plants to be infested were not in compartment during fumigation and ventilation periods*						
4	(A)	22	0.36	12.55	0.64	6.45
	(B)	22	3.00	13.41	3.59	0
7	(A)	6	0	11.84	0.33	7.83
	(B)	6	2.17	15.00	2.83	0
(3) *Control*	(A)	20	18.95	0.10	0.30	0.65
	(B)	11	17.55	0.09	2.36	0

*A replicate comprised one leaf populated with 20 adult females.
**(A) method, petiole ringed with tanglefoot; (B) method, edge of leaf ringed with tanglefoot.

When leaves were not populated with mites until the morning following the day of ventilation, mite mortality was low, although there was evidence that some toxic fumes still remained in the compartment (Table III).

TABLE III. Mortality of adult females of *T. urticae* placed on plants one day after a greenhouse compartment treated with naled was ventilated for four or seven hours

Ventilation period (hours)	Location of mites during tests	No. of replicates*	Average no. mites alive per replicate	Average no. mites dead per replicate	No. mites in tanglefoot**	No. mites which left plant
4	On lower surface of leaf *in situ* on plant (A)	16	16.81	2.19	0.19	0.81
	On detached leaf on pad of moist absorbent cotton in petri dish (B)	8	13.63	2.50	3.87	0
7	(A)	11	15.73	1.91	0.45	1.91
	(B)	10	14.50	2.60	2.90	0
Control	(A)	20	18.95	0.10	0.30	0.65
	(B)	11	17.55	0.09	2.36	0

*A replicate comprised one leaf populated with 20 adult females.

**(A) method, petiole ringed with tanglefoot; (B) method, edge of leaf ringed with tanglefoot.

Discussion

The results of this investigation showed that naled is a very effective chemical for mite control when used in a tightly-sealed greenhouse compartment. The high mortality rate of quiescent stages was unexpected, since only the active forms appear to be controlled in cucumber greenhouses. A similar limitation in efficacy with naled was observed by Glancey *et al* (1961) in rose greenhouses. Apparently the commercial greenhouses are not sufficiently airtight to confine all of the vapor.

Glancey *et al* (1961) recommended a schedule of three applications of naled three days apart, plus follow-up treatments as required, to ensure control of *T. urticae* in rose greenhouses. A similar schedule should be appropriate in cucumber greenhouses. Growers who make single applications, or follow a once per week schedule, will not obtain effective control.

The high mortality of adult mites in our compartment showed that seven hours of continuous ventilation were insufficient to remove all traces of naled. Since cucumber greenhouses must be vented away from the wind, and cannot remain open for long periods during cold, cloudy weather, proper aeration of these structures is even more difficult. To prevent possible harm to bees, growers should ventilate their greenhouses as often as possible on the day succeeding a naled fumigation and remove or protect the bees until the second morning after treatment.

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PEPPER INSECTS IN SOUTHWESTERN ONTARIO

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Abstract

The biology and control of the principal insect pests of peppers in southwestern Ontario are reviewed. Insects discussed are the pepper maggot, *Zonosemata electa* (Say), the green peach aphid, *Myzus persicae* (Sulzer), and the European corn borer, *Ostrinia nubilalis* (Hübner). Effective control of the maggot and aphid is possible, but corn borer infestations remain a serious problem.

Introduction

The total crop value of peppers ranks well below many of the other crops grown in Ontario. The total commercial planting of peppers in the province in 1967 was only 1,030 acres, with a value just over $797,000 (Ontario Department of Agriculture and Food, 1968). However, it should be noted that over $575,000 of this figure was earned in Essex and Kent Counties. The average yield of peppers in these counties was 750 bushels per acre, compared with 250 bushels or less in all other areas. The average net farm price per bushel was $1.35. Thus peppers are a valuable cash crop to many growers in southwestern Ontario.

The three principal insect pests of peppers in southwestern Ontario are the pepper maggot, *Zonosemata electa* (Say), the green peach aphid, *Myzus persicae (Sulzer),* and the European corn borer, *Ostrinia nubilalis* (Hübner). The authors recently completed a seven-year study of the biology and control of these pests. This paper summarizes both published and unpublished data to provide a comprehensive review for future investigators.

Pepper Maggot

Hosts, Distribution and Economic Importance

Host plants of the maggot in southwestern Ontario are peppers, horse nettle *(Solanum carolinense* L.*),* and occasionally eggplants. Tomato and several weeds in the Solanaceae family have also been reported as hosts in the United States (U.S.D.A., 1959).

Prior to 1956, the known distribution of the maggot was limited to the United States in an area extending from New York and Massachusetts to Indiana and southward to Florida and Texas (U.S.D.A., 1959). In 1956, the maggot was found in a field of peppers near Harrow and by 1961 it had spread over most of Essex County. One field had 90% of the fruits infested and infestations in the 30 to 40% range were common. Not only was there a major loss of revenue in the marketing of fresh fruits, but a local canning factory was plagued with consumer complaints because maggots were found in jars of preserved peppers.

Seasonal History

The insect overwinters as a pupa, commonly in the top 2 inches of soil (Foott, 1963). Adults emerge in late June or early July and reach a peak around mid-July. Eggs are deposited in the walls of pepper fruits and with careful examination can usually be detected within the small ovipositional puncture. In a severely in-

fested field up to 18 eggs per fruit might occur, and infestations of 7 to 11 eggs per fruit are common.

Most larvae on hatching bore through the wall to the inner surface of the fruit and feed in the spongy placental tissue. In some instances, however, feeding is confined entirely to the wall or both the wall and placenta are utilized. Mature larvae make an exit hole and drop to the ground to pupate.

Less than 30% of overwintered pupae collected from infested fields produced adults. A similar low survival rate was noted by Burdette (1935) in New Jersey.

Based on the first detection of various stages in the field, it appeared that the minimum periods required for preoviposition, incubation of the eggs, and larval development were 6, 12, and 18 days, respectively. There is one generation per year.

Control

A study of the insect's seasonal history showed that two important factors would have to be considered when devising control methods. First, because the egg was protected in the wall of the pepper and the larva within the fruit, it was imperative to find insecticides which would kill the adults prior to oviposition. Secondly, since adult flies were seldom seen unless the plants on which they were resting were disturbed, an imminent infestation would go undetected. It would be necessary to persuade growers to treat their fields at a specified time each year rather than wait for evidence of an infestation.

A number of candidate insecticides were tested and from these endosulfan and malathion at 0.75 and 1.5 pounds actual toxicant per acre, respectively, were selected, with the recommendation that four applications be made at weekly intervals starting in late June or very early July (Foott, 1963). Endosulfan was considered the preferred material because it also provided effective control of aphids. Further research showed that the rate of endosulfan could be reduced to 0.5 pound actual per acre.

The recommended control program proved to be so effective that no maggot infestations have been reported or observed in pepper fields in recent years.

Laboratory Rearing and Biology

The reports of other workers showed that laboratory rearing of this insect might be impossible (Peterson, 1923; Burdette, 1935). They used various types and sizes of cages and provided the flies with pepper plants, sprigs of the plant with peppers on them, and young peppers by themselves. Sweetened water was provided for food. The adults only survived for a few days and no oviposition occurred. A similar approach by the senior author also proved unsuccessful.

Long periods of observation showed that captive flies confined almost all of their activities to the top of the cage and never visited the sweetened water or pepper fruits which had been placed on the cage floor. At this point, sucrose-moistened strips of absorbent cotton were placed across the saran screen top of the cage and potted pepper plants were inserted for oviposition. With this arrangement the flies lived an average of 17 days and deposited viable eggs. The larvae matured, pupated, and gave rise to adults to complete a full generation. Further refinements to the rearing technique followed (Foott, 1968b).

Laboratory propagation permitted the authors to obtain the following additional knowledge of the maggot's biology.

1. *Oviposition:* The preoviposition period varied widely when small numbers of flies were caged, but oviposition usually started within 7 or 8 days when large numbers of both sexes were present. Dissection of females at various intervals

after emergence established that egg maturation required 6 to 7 days. This means that adult flies would be exposed to insecticides in treated fields for a relatively long period prior to oviposition and probably explains the excellent control which occurred.

Prior to this investigation, the insect's potential fecundity could only be estimated by dissecting the ovaries of field-collected females. The authors obtained more pertinent data by rearing adults in the laboratory, feeding them during the egg-maturation period, and releasing them in a large cheesecloth cage which enclosed 60 pepper plants in the field. Later examination of the peppers revealed that 17 females had deposited an average of 41.6 eggs. This was considerably higher than the numbers obtained when adults were dissected (Peterson, 1923; Foott, 1963).

2. *Adult Longevity:* The average longevity of females and males was 22.5 and 16.4 days respectively, when fed a dilute sucrose solution in the greenhouse. Although the longevity and food sources of flies in the field could not be determined, flies caged with aphid-infested pepper plants in the greenhouse lived up to 21 days and oviposited. Honeydew secreted by the aphids was the only source of moisture and nutrition. Since pepper plants are usually infested with the green peach aphid, it is probable that honeydew is a major source of food for maggot adults in nature.

3. *Pupal Mortality:* Groups of pupae which were reared in the laboratory and stored in sterilized sand at 35°F had an average survival rate of 73.6%. This suggests that the high mortality of overwintered pupae in the field is due to the effects of low temperatures and infection by soil microorganisms rather than to a low natural viability.

4. *Egg and Larval Development:* Although the 12-day incubation period for eggs as estimated from field observations seemed excessive, laboratory data showed that this was a realistic figure. The incubation period in a rearing room with an average temperature of 71.3°F was 13.1 days. In a greenhouse, where the temperature ranged from 52 to 106°F, eggs hatched in 12 days.

The time required for larval maturation in the rearing room was 17 days, which closely approximated the 18 days estimated in the field.

Importance of the Wild Host

Horse nettle, *Solanum carolinense* L., is the only known wild host of the maggot in Ontario. It is a prickly perennial with creeping subterranean rhizomes and bears yellow fruits which grow to a maximum of 1.5 cm in diameter. Patches of this weed were examined to determine its importance as a host and to ascertain if two distinct races of the maggot were involved in pepper and horse nettle infestations.

The incidence of horse nettle in Essex County is not great, as only seven patches were located. There were notable differences between development of the insect in pepper and horse nettle (Foott, 1968a). Whereas egg deposition started in early July in pepper fields, no fruits were present on horse nettle at this time, and oviposition did not commence until early August. The majority of the larvae matured during August in peppers, but during September in horse nettle. The larval, pupal, and adult stages were all smaller when development occurred in the fruits of horse nettle.

Despite the difference in host plants, periods of infestation, and size, there was no evidence that distinct host races had developed. Flies reared from larvae which had developed in pepper fruits oviposited in the fruits of horse nettle and vice versa, and larvae matured in both instances. Since peppers are available for oviposition when adults emerge from horse nettle patches, but the

reverse situation does not apply, it is logical to conclude that initial infestations of the maggot in Essex County occurred in horse nettle.

Although the maggot has been controlled in pepper fields, it remains a potential pest as long as breeding populations exist in horse nettle. Growers have been informed of this possibility and advised how to eradicate the weed.

Green Peach Aphid

Infestations of the green peach aphid are an annual problem to pepper growers. The aphid reduces plant vigor, transmits virus diseases, and causes the fruits to be sticky and dirty by its deposition of honeydew. All varieties of peppers examined were highly susceptible to attack.

Although the aphicides registered for use as sprays on peppers should be effective when applied at proper intervals, reports of unsatisfactory control were frequently received. The first complaints commonly occurred in early August when growers stated that a material which controlled aphids earlier in the season was no longer effective. Usually, however, these initial reports coincided with the period of maximum buildup of aphid populations and the large numbers of aphids in treated fields reflected inadequate spray coverage on the lower surfaces of leaves rather than a change in the efficacy of the aphicide.

Control

To obtain effective aphid control on the lower surfaces of leaves when pepper plants become large and compact, it was apparent that a long-lasting systemic insecticide was required. A three-year study showed that one annual side-dressing with disulfoton around mid-June, at a rate of 2 pounds actual toxicant per acre, controlled aphids throughout the entire period that they were most prevalent in pepper fields (Foott *et al,* 1969). The total percentage reductions throughout the period from 3 to 9 weeks after placement of the insecticide in 1965, 1966 and 1967 were 88.7, 98.2 and 98.2, respectively.

Disulfoton was first registered for use on peppers in Canada in 1967, but must not be applied closer to harvest than 90 days. To ascertain if this interval could be reduced, leaf and fruit samples from treated pepper plants were collected at intervals of 42, 50, and 60 days after treatment and checked for residues of disulfoton or its insecticidal metabolites. Analyses of the samples showed that there were no detectable amounts of disulfoton or its oxidation products in the fruit on any sampling date, but appreciable amounts of the insecticide or its oxidation products were present in the leaves on all sampling dates (Foott *et al,* 1969). The data indicate that the required interval of 90 days between treatment and harvest could be reduced and thus permit the use of disulfoton on varieties which can be harvested 65 to 75 days after planting.

European Corn Borer

The European corn borer has two broods in southwestern Ontario, but only the second brood infests peppers. Eggs are laid on the undersides of leaves and newly-hatched larvae move to the fruits where they bore into the cap area. As with the pepper maggot, there is often very little external evidence that a fruit is infested.

A survey of pepper fields revealed large variations in the degree of borer infestation, and it appeared that these variations might be related to differences in varietal susceptibility. Subsequently, plots of peppers were planted at the research station, with each plot comprising three varieties of the bell type sweet

pepper (Keystone Resistant Giant, Staddon's Select, and Vinedale) and one variety each of the pimento, yellow sweet, and yellow hot types. No insecticides were applied for borer control.

In a 5-year study it was found that Keystone Resistant Giant consistently had the greatest borer infestation and the yellow hot type the least (Table I). The

TABLE I. Varietal susceptibility of peppers to European corn borer

Year	No. peppers examined per variety	% of fruits infested per variety					
		Keystone Resistant Giant	Staddon's Select	Pimento	Vinedale	Yellow sweet	Yellow hot
1963	140	31.4	9.3	2.9	5.0	2.1	0.7
1964	100	36.0	29.0	21.0	10.0	16.0	4.0
1965	150	32.0	16.7	10.0	9.3	10.0	4.0
1966	700	62.3	49.7	43.1	45.4	30.3	12.3
1967	880	42.7	25.6	31.0	26.5	8.4	3.5
	Averages	40.9	26.1	21.6	19.2	13.4	4.9

relative immunity of the yellow hot type appeared to be due to a low egg deposition on the plants rather than to a high mortality of larvae which sought to invade the fruits. The survival rate for small larvae inserted into hot peppers in the laboratory was similar to that for larvae inserted into the sweet types.

The borer has proved a difficult insect to control because of the long interval during which second brood eggs are deposited and the inability of many growers to obtain proper coverage of the plants with insecticides. The latter situation applies particularly to varieties such as Keystone Resistant Giant which have a compact type of growth. The establishment of effective control is further complicated by the fact that newly-hatched larvae do not appear to feed on foliage, as is the case in corn, but move directly to the fruits. Therefore frequent treatments are required to ensure that the insecticide residue is sufficient to destroy larvae before they reach the fruits.

No insecticide tests were conducted specifically for control of the borer, but it was shown that disulfoton applied as a side-dressing in aphid control studies was ineffective against the borer (Table II). Since the larvae do not feed on foliage, soil-incorporated systemic insecticides do not offer much promise. Effective control might necessitate a combination of two insecticides per treatment, one to destroy eggs and the other to kill larvae.

TABLE II. Effect of disulfoton on infestations of the European corn borer in peppers

Variety	Treatment	% of fruits infested by borers			
		Plots*			
		I	II	III	Averages**
Vinedale	Side-dressed with disulfoton June 14	39.1	27.8	41.3	36.1
	Side-dressed with disulfoton July 15	45.5	37.3	35.4	39.4
	Check	43.3	33.7	37.6	38.2
Staddon's Select	Side-dressed with disulfoton June 14	54.4	52.5	52.9	53.3
	Side-dressed with disulfoton July 15	56.8	45.1	49.8	50.6
	Check	55.8	40.5	49.1	48.5

*The number of plants examined per plot in each treatment ranged from 49 to 59.
**There were no significant differences between treatments for either variety.

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AN ANALYSIS OF THE POSSIBILITIES OF THE STERILE MALE RELEASE TECHNIQUE IN THE ERADICTION OF THE SUGARCANE MOTH BORER, *DIATRAEA SACCHARALIS* (F.), IN BARBADOS, WEST INDIES

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Abstract

The sugarcane moth borer, *Diatraea saccharalis* (F.), is an important pest in parts of America where sugar is grown. The possibility of using the sterile male release technique for control is discussed.

Analysis and Discussion

The sugarcane moth borer, *Diatraea saccharalis (F.)* has been an important economic pest of sugarcane in Central and South America, the West Indies, and the southern parts of the United States of America. "Classical" biological control has been very effective in reducing the incidence of the pest to "economic zero" in certain parts of its geographic range, whereas in some areas no effective control has been achieved either by chemical or biological control.

In assessing the theoretical possibilities of using this method certain aspects of the physical and biotic environment should be analyzed — the size of the geographic range of the species; whether populations are isolated or contiguous; the presence or absence of other species of cane borers and the theoretical effects of eradication of *D. saccharalis* on the populations of these species; the terrain, and possibly wind velocity.

Historically most of the work done on the cane borer, *Diatraea saccharalis,* has been geared towards chemical or classical biological control. Except in a few cases these methods have not been noteworthy for an ecological approach. (Van Whervin, 1963, 1966). Therefore information of an ecological nature needed for the sterile male release is lacking. The feasibility of the method rests on the following: firstly we must determine if there is a suitable stage in the life cycle of the moth borer at which we can obtain dominant lethal mutation (or the desired kind of sterility) with a high percentage survival up to and including the sterile males for release. This work has been attempted in Puerto Rico using the gamma cell and chemosterilants. On a visit to Puerto Rico in 1964 one of the authors was told that the very high mortality of pupae from these sources made this technique unfeasible in the control of the sugar cane moth borer. It seems very likely that the first step towards a program of sterile male release would be a detailed study of the reproductive physiology of this pest with the aim of discovering the critical stage at which irradiation or chemosterilant could be applied to obtain:

1. dominant lethal mutation
2. high percentage survival
3. fully competitive males.

As far as we are aware the question of the polygamy or monogamy of *D. saccharalis* has not been settled. It is generally believed, however, that the species is monogamous. Some authors have laid great emphasis on monogamy as a necessary prerequisite in the sterile-release method. This characteristic evidently simplifies but it certainly does not invalidate the method against polygamous insects. Polygamy simply requires that the following criteria be met:

1. That the sterile males transmit sperm containing dominant lethal mutations that are competitive with the sperm contributed by normal males.

2. That the sterile males should contain a sufficient store of mature sperm or spermatids at the time of irradiation to last through the number of matings normally experienced by the males of this species in the field. If this criterion is met then the mathematics of numbers required for eradication is identical for monogamous as well as polygamous species.

The next question we must examine is whether or not *D. saccharalis* lends itself to mass propagation — vast numbers are likely to be required in a sterile male release program. In the mass production of *Trichogramma minutum* (Riley), an egg parasite of the moth borer, another host was used which lends itself more suitably to laboratory rearing. An even greater difficulty is to rear the larvae in captivity. Preliminary research has been done by the writer and others to mass-produce *D. saccharalis* but these methods were not highly successful (Van Whervin, 1966). It will therefore require laboratory research to formulate a suitable diet for moth borer larvae. Equally important is a determination of the optimum conditions for rearing to obtain not only the maximum numbers of larvae but also other stages in the life cycle. An efficient method of mass propagation must be discovered to make the sterile male release of *D. saccharalis* a practical feasibility. A corollary to mass propagation is a study of the most efficient method of release of sterile males.

We are somewhat skeptical of many theoretical models and are of the opinion that mathematical models should, in the final analysis, be formulated from a profound knowledge of the ecology of the organism gained from both laboratory and field-ecology studies. A mathematical model of the sterile male release method for *Diatraea* at this stage would be highly speculative. Some authors have greatly emphasized the need at times to reduce populations of the subject species initially by chemical insecticides and other artificial methods prior to the application of the sterile male release. They have not however given equal emphasis to the possibility that at certain periods of the year natural populations of insects may attain a very low population level — a level equivalent to or below that achieved by chemical insecticides. If this assumption is correct it seems very reasonable therefore to suggest that as a preliminary step to the sterile male release that adequate manpower be diverted to obtaining quantitative data on population fluctuations in time and place. Preliminary data on population growth of *Diatraea* do suggest that such troughs in populations do occur. Those who have suggested the use of chemicals to initially reduce the pest populations make little or no reference to the possible disruption of the ecosystem in using chemical insecticides to obtain a low level of population prior to initiation of the sterile male release. Possible insecticidal residues may affect the survival of sterile males (this may be minimal but the possibility nevertheless exists). To obtain a drastic reduction of populations of moth borer by chemical insecticides requires proper timing and placement of the spray mixture because of the manner of behavior of the insect: the larvae spend almost 100% of their life in the stalk of the cane.

We need to have more than a general idea of what numbers of sterile males are needed for release (this figure can be obtained by studies of a quantitative nature). We may also need precise data on the reproductive replacement rate of the species where chemical control is attempted and under varying environmental conditions. These data can be obtained under controlled conditions in the laboratory and we see no reasons why these data cannot be obtained in the field.

A most important consideration in assessing the feasibility of the potential use of the sterile release method is the economics of the method used in the control or eradication of the moth borer. The feasibility of the sterile male release will obviously depend primarily on its cost factor and the annual economic loss due to

the attack of the moth borer. The cost of eradication will be weighed against its long-term economic returns. The cost of the project will depend on factors such as:

1. the geographic range of the species
2. the size of the population and the terrain of the country
3. the cost of mass production of *Diatraea*
4. the cost of buildings in which to rear *Diatraea*
5. the cost of manufacturing synthetic foods
6. the cost of a Gamma cell or of chemosterilants
7. the salary of entomologists and specialists in this type of work
8. the wages of technicians and casual workers.

The cost factor may vary depending on the factors listed above. We think it is a fair generalization to make that this method is very expensive and can only be utilized by countries that can afford and have adequate research personnel to do the fundamental research. Even though the long-term economic returns may justify this method we doubt very much that most of the countries in which *Diatraea saccharalis* is found could be persuaded to use this method of control because of the large initial capital required and the uncertainty of its success. In conclusion, we will say that this method of pest control is too expensive in terms of research personnel and capital, and the results too erratic for some countries to consider.

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HORMONAL CONTROL OF LIPID CONCENTRATION IN FAT BODY AND HEMOLYMPH OF THE AMERICAN COCKROACH, *PERIPLANETA AMERICANA*

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Abstract

Extracts of the corpus cardiacum-corpus allatum complex injected into adult male cockroaches cause a depletion in hemolymph triglyceride content. Concomitant with this hypolipemic state is an increased fat body triglyceride content. The factor responsible for the effect has been shown to be contained in the corpus cardiacum.

Introduction

It has been known for some time that the principal energy reserves in insects, as in mammals, are neutral lipids stored in the fat body. Beall (1948) demonstrated the utilization of stored lipid during the long migratory flight

of the monarch butterfly, while Weis-Fogh (1952) showed the importance of this reserve in long distance flights of locusts.

These observations resulted in much work being devoted to elucidating the mechanisms by which lipid is released from fat body and subsequently transported to flight muscle. Of particular significance have been the studies of Tietz (1962) who showed that insect hemolymph, in contrast to Ringer's solution, was able to stimulate the release of glycerides from fat body. Also of interest is the work of Chino and Gilbert (1964) who demonstrated the importance of diglyceride in the transport of lipid from fat body to hemolymph.

Most work on lipid transport has concentrated on mobilization of reserves, and a survey of the literature reveals a lack of information on the movement of lipid to the storage depots following feeding. The present study has, therefore, been concerned with transfer of lipid from hemolymph to fat body.

Methods

Insects used in the study were taken from a colony maintained in the laboratory and used about two months after the final molt.

Gland extracts were prepared, initially, from the entire corpus cardiacum-corpus allatum complex, and subsequently from the separated glands. The glands were homogenized in distilled water and the extract boiled for 3 minutes prior to centrifugation. The concentration of the supernatant was adjusted so that 10 μl contained the desired concentration of extract. In each experiment the desired tissues were removed one hour after injection of extracts.

Hemolymph was collected through the antennae by the centrifugal technique first described by Sternburg and Corrigan (1959), care being taken to maintain the temperature of hemolymph at 0°C. Neutral lipids were extracted from the tissue under investigation using a slight modification of the method of Folch *et al* (1955), and the separate glyceride fractions separated by chromatography on Florisil according to the method of Carrol (1961). Quantitative determinations of neutral glyceride concentration utilized the colorimetric test of Rapport and Alonzo (1955), while free fatty acids were determined according to Dole and Meinertz (1961).

Results and Discussion

The control and experimental value for any one experiment represent a pooled sample of tissue from 12 insects.

Table 1 shows the effect on hemolymph neutral lipid concentration caused by injecting a combined extract of the two glands. It can be seen that the

TABLE I. Effect of corpus cardiacum-corpus allatum extract on hemolymph neutral lipid levels

	Control	Hormone	P
Triglyceride	950.6 ± 98.4*	586.2 ± 76.2	0.01
Diglyceride	2,304.5 ± 298.6	1,929.3 ± 248.3	0.20
Monoglyceride	112.0 ± 22.2	134.8 ± 37.3	0.50
Free fatty acids	128.6 ± 26.8	116.9 ± 24.7	0.50

*Values expressed as μg palmitate glyceride per ml hemolymph.
Figures given represent the mean of nine experiments ± standard error of the mean.

extract has a strong effect on both triglyceride and diglyceride levels, causing a marked decrease in the concentration of both fractions one hour after injection.

The rapid removal of a relatively large quantity of lipid suggests that it is being stored in another tissue, the most probable site being the fat body.

The effect of the extract on fat body neutral lipid content was investigated and the results are shown in Table II. The results support the hypothesis that the active factor released from the corpus cardiacum-corpus allatum causes an uptake of neutral lipid from hemolymph by the fat body.

TABLE II. Effect of corpus cardiacum-corpus allatum extract on fat body neutral lipid levels

	Control	Hormone	P
Triglyceride	77.29 ± 5.68*	89.02 ± 4.71	0.05
Diglyceride	3.08 ± 0.71	4.50 ± 1.02	0.10
Monoglyceride	0.58 ± 0.20	0.63 ± 0.08	0.50
Free fatty acid	0.16 ± 0.06	0.12 ± 0.05	0.50

*Values expressed as μg palmitate glyceride per mg fat body.

Scharrer (1962) has carried out extensive histological studies of the endocrine glands of *Periplaneta americana,* and has shown that due to the invasion of corpora allata tissue by corpora cardiaca tissue, normal dissection techniques are unable to completely free corpora allata from corpora cardiaca. Thus, in order to determine which of the two glands is responsible for the hypolipemic effect it was necessary to employ a dilution technique similar to that used by Steele (1969). The effect of injecting dilute extracts of the two glands is shown in Table III, and indicates that the hypolipemic factor is released from the corpus cardiacum.

TABLE III. Effect of dilute extracts of corpus cardiacum and corpus allatum on hemolymph triglyceride levels

Corpus Cardiacum	Concentration	Control	Hormone	% Decrease
	1/50	723.6 ± 151.6*	331.6 ± 75.9	54.1
	1/100	668.7 ± 110.4	385.0 ± 67.2	42.4
	1/200	783.2 ± 251.8	471.4 ± 120.0	39.8
	1/50	780.0 ± 98.7	506.3 ± 48.6	35.0
Corpus Allatum	1/100	759.2 ± 99.8	598.2 ± 92.2	21.2
	1/200	818.0 ± 104.0	677.2 ± 136.8	17.2

*Values expressed as μg tripalmitin per ml hemolymph

These results also show that an effect is obtained at concentrations which can be considered physiologically meaningful.

The results clearly demonstrate the presence of a factor in the corpus cardiacum of *Periplaneta americana,* capable of stimulating the uptake of glycerides

from hemolymph by fat body. This finding contrasts with the report of Mayer and Candy (1969) who demonstrated an increased output of diglyceride by the fat body in the presence of corpus cardiacum extract. These studies were performed on the desert locust, *Schistocerca gregaria,* and it is possible that both factors are present in both insects, the relative amounts and importance of each depending on the species concerned and its physiological condition.

The site of action of the hypolipemic factor has not yet been determined, nor is it known whether the uptake of each glyceride fraction is stimulated independently. The work of Chino and Gilbert (1964) showed that diglyceride is the form in which lipid is transported from the fat body to hemolymph. The information obtained in the present study would suggest that the same diglyceride fraction may be of equal importance in the transfer of lipid in the opposite direction.

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A KEY TO FREE-FEEDING SAWFLY LARVAE ON BIRCH AND ALDER IN ONTARIO

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Abstract

A key for identification of larvae of sawflies, including 15 species in Tenthredinidae, 3 in Argidae and 2 in Cimbicidae is presented, including illustrative figures.

Introduction

The Forest Insect and Disease Survey in Ontario has collected and identified a wide range of insects for over 20 years. The majority of these are injurious, and are most readily detected and collected during their larval stage. To facilitate identification, larval keys have been developed at Sault Ste. Marie from information drawn from the entomological literature and from morphological studies of new or little-known species.

The following key deals with the advanced stages of free-feeding sawfly larvae on birch, *Betula,* and alder, *Alnus,* and includes 15 species in Tenthredinidae, 3 in Argidae, and 2 in Cimbicidae. Representative adults were identified by Dr. H. E. Milliron, Entomology Research Institute, Ottawa, Ontario. However, five species are named to genus only, and others are tentative, pending a revision of the North American Tenthredinoidea. Diagnostic characters of the larvae in the key are figured, as is the third abdominal segment for most species. The number of setae, pores, or sensory structures referred to as sensilla styloconica (glandubae of Yuasa, 1922) on abdominal segments usually varied somewhat among individuals in a species, so "average" specimens were selected for the illustrations. The month(s) preceding the species' name in the key refers to the known seasonal occurrence of the larval stage. The works of Yuasa (1922), Lorenz and Kraus (1957), Peterson (1948), and Raizenne (1957) were referred to extensively during this study.

Key to Larvae

1. Thoracic leg with empodium next to claw (Figure 1); third abdominal segment with three annulets, all setiferous; antennae one-segmented ..... (Argidae) 2

   Thoracic leg without empodium next to claw 4

2. Larvapods on abdominal segments 2 to 7 and 10; head with dark streak along coronal suture, antennae button-like (Figure 2). Abd. seg. 3 (Figure 9). July, August ..... **Arge clavicornis** (F.)

   Larvapods on abdominal segments 2 to 6 and 10; head without streak along coronal suture, antennae conical (Figure 3); body with rows of black spots 3

3. Epiproct and thoracic legs yellowish; head yellow-orange. Abd. seg. 3 (Figure 10). July to September ..... **Arge pectoralis** (Leach)

   Epiproct with a dark blotch; thoracic legs dark; head yellow-orange to near black. July to September ..... **Arge** sp.

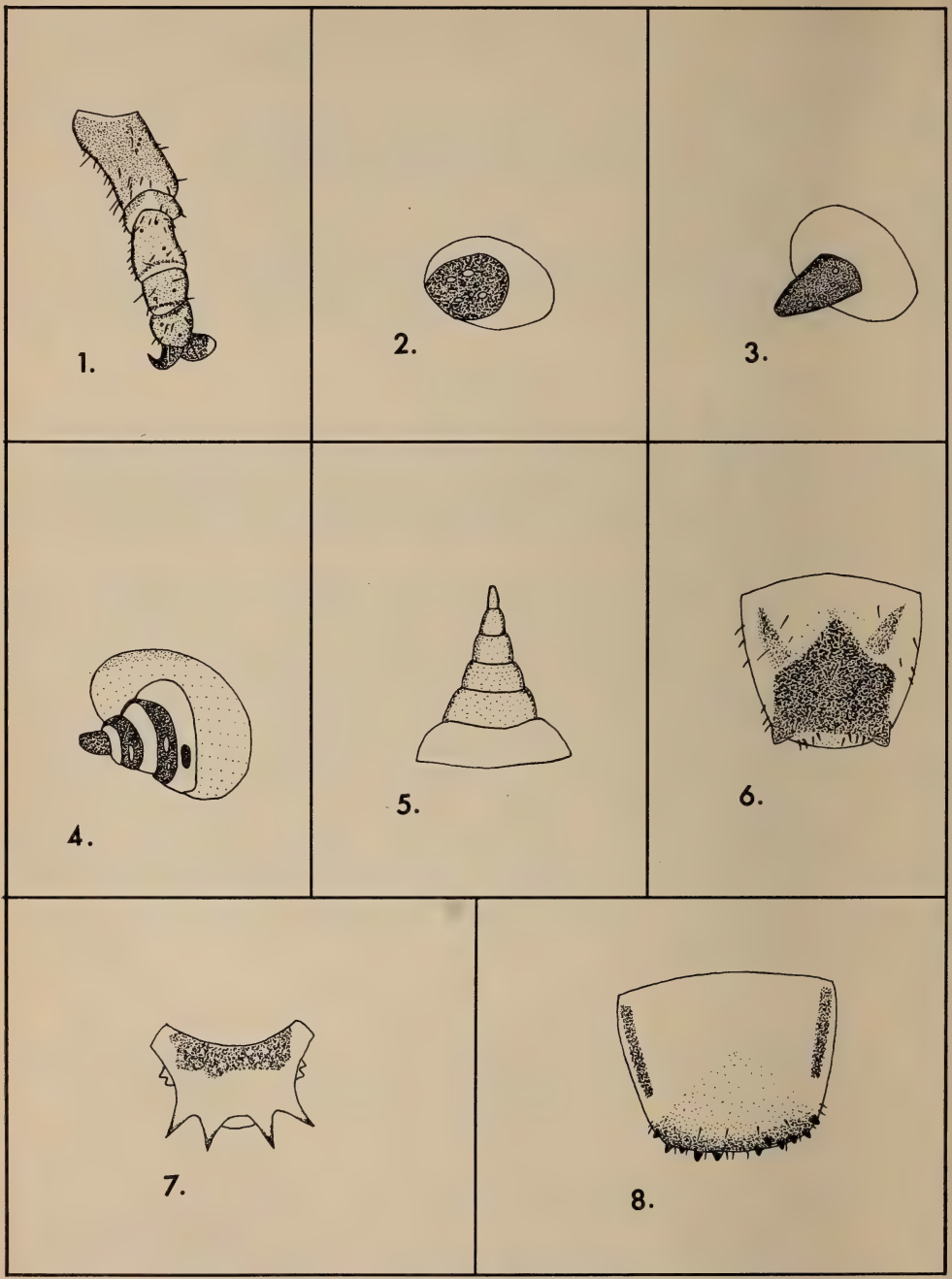

FIGURE 1. Thoracic leg of argid larva.

FIGURES 2-5. Larval antenna. 2, *Arge clavicornis* (F.); 3, *Arge pectoralis* (Leach); 4, *Nematus erythrogaster* Nort.; 5. *Dimorphopteryx melanognathus* Roh.

FIGURES 6-8. Epiproct. 6, *Croesus latitarsus* Nort.; 7, *Dimorphopteryx melanognathus* Roh.; 8, *Hemichroa crocea* (Four.)

4. Antenna a single conical segment; a gland dorsad of each spiracle on abdominal segments 2 to 8 (Figure 11); larva large. (Cimbicidae) 5

Antenna four- or five-segmented (Figures 4 and 5); supraspiracular gland absent (Tenthredinidae) 6

5. Body pale green, yellow, or orange, with black middorsal stripe. Abd. seg. 3 (Figure 11). June to September ..... **Cimbex americana** Leach

Body pale greenish without dark dorsal stripe. June to August ..... **Trichiosoma triangulum** Kby.

6. Larvae on birch 7

Larvae on alder 18

7. Larvapods on abdominal segments 2 to 7 and 10 8

Larvapods on abdominal segments 2 to 8 and usually 10 (reduced on 8 in striped larvae of **Hemichroa** 15

8. Anal protuberances present (Figure 6) 9

Anal protuberances absent 12

9. Dark markings on body; head without three conspicuous dark streaks; antenna with segment 1 reduced, segments 2 and 3 complete rings, and segment 4 peg-like 10

Body pale with subdorsal yellow fat patches; head whitish with a dark streak along coronal suture and a lateral streak above each ocellus; antenna with segments 1, 2, and 3 reduced, 4 peg-like. Abd. seg. 3 (Figure 12). Solitary in June, August, and September ..... **Nematus pinguidorsum** Dyar

10. Head pale with reddish brown freckles; sensilla styloconica absent on body 11

Head blackish; sensilla styloconica present though small (Figure 13); body pale to brown (young larvae near black) with large, dark, supraspiracular spots on thoracic segment 2 to abdominal segment 9; epiproct marking and anal protuberances usually dark (Figure 6). Abd. seg. 3 (Figure 13). June, August, and September ..... **Croesus latitarsus** Nort.

11. Epiproct markings dark brown, large, pitted; anal protuberances short and dark; body pale with indefinite dark middorsal line; dorsum dark brown on prothorax, paler on meso- and metathorax; abdominal segments with a dark area behind, above and below the spiracle; dark longitudinal sclerites at base of larvapods; segmental dark brown markings between larvapods. Abd. seg. 3 (Figure 14). August ..... **Nematus latifasciatus** Cress.

Epiproct marking and anal protuberances light brown; body with dark middorsal line broken and fading out posteriorly; spiracular stripe dark, broken; dark brown sclerites below spiracles; dark, broken midventral line on abdomen. Abd. seg. 3 (Figure 15). June to August ..... **Nematus** sp. #1.

12. Body setae sparse, much shorter than a larvapod; antenna 4 segmented, flattened, but with terminal segment peg-like 13

Body setae numerous, as long or longer than a larvapod; body with gray dorsum but pale from spiracular area to venter; head pale with dark cap and a dark spot about ocelli and posteriorly; epiproct pale. Abd. seg. 3 (Figure 16). June and August ..... **Priophorus betulae** Roh.

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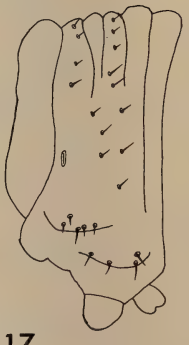

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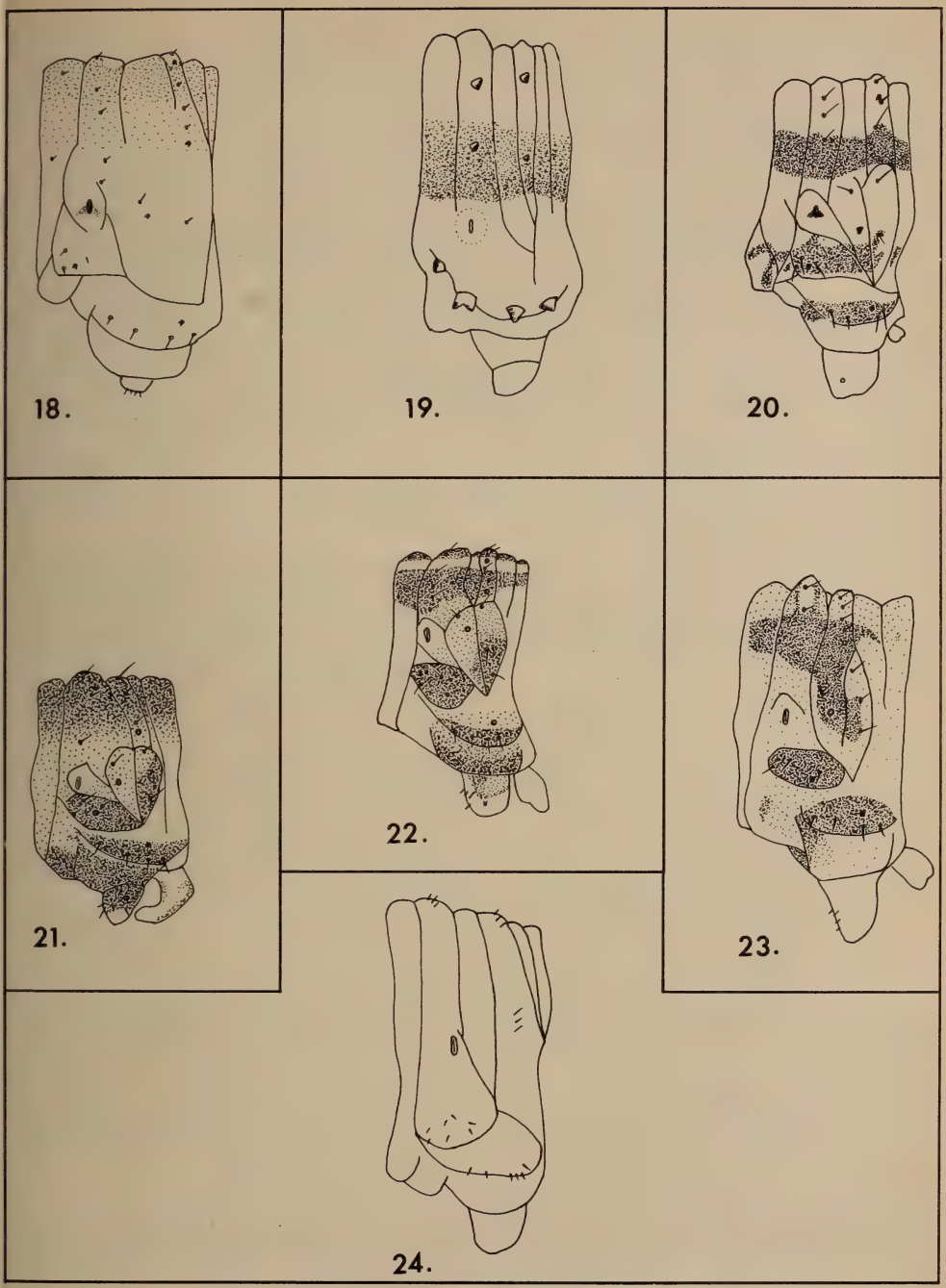

FIGURES 9-24. Third abdominal segment. 9, *Arge clavicornis* (F.); 10, *Arge pectoralis* (Leach); 11, *Cimbex americana* Leach; 12, *Nematus pinguidorsum* Dyar; 13, *Croesus latitarsus* Nort.; 14, *Nematus latifasciatus* Cress.; 15, *Nematus* sp #1; 16, *Priophorus betulae* Roh.; 17, *Pristiphora cadma* W. and R.; 18, *Amauronematus* sp.; 19, *Dimorphopteryx melanognathus* Roh.; 20, *Hemichroa crocea* (Four.); 21, *Nematus* sp. #2; 22, *Nematus erythrogaster* Nort.; 23, *Nematus umbratus* Thoms.; 24, *Eriocampa ovata* (Linn.)

13. Epiproct raised medioposteriorly and bearing raised, pointed setal bases; sensilla styloconica absent; body pale with dark spinules and setae; legs with some dark pigment on coxa and trochanter, claws dark red-brown; head gray-brown with dark freckles, frons and streak above ocelli dark brown. Abd. seg. 3 (Figure 17). June to August ..... **Pristiphora cadma** W. and R.

Epiproct not as above; sensilla styloconica present and dark 14

14. Body pale, dorsum gray with four transverse whitish markings on most segments of single specimen studied; spiracles winged; head yellow in preserved larva with slightly darker freckling; antennal segments 1 to 3 incomplete, segment 4 only slightly raised. Abd. seg. 3 (Figure 18). June ..... **Amauronematus** sp.

Body pale, concolorous; head light green in living specimen. (No preserved specimens available for study.) June ..... **Amauronematus fallax** (Lep.)

15. Anal protuberances present, though modified and more than the usual single pair (Figures 7 and 8); antenna 5-segmented 16

Anal protuberances absent 17

16. Head orange-brown, dorsally prominent with black cap at apex; antenna elongate (Figure 5); body pale with a wide dark supraspiracular band; a lateral row of fringe-like protuberances, smaller pairs dorsally, two pairs posteriorly on epiproct (Figure 7). Abd. seg. 3 (Figure 19). July and August ..... **Dimorphopteryx melanognathus** Roh.

Head black with paler transverse line above frons; antennal segments 1 and 2 nearly obsolete, segments 3 to 5 conical; body pale with a dark prominent supraspiracular stripe and two broken dark subspiracular stripes; 8 to 10 short, dark-tipped, pointed anal protuberances (Figure 8); larvapods on abdominal segment 8 reduced in size. Abd. seg. 3 (Figure 20). August and September ..... **Hemichroa crocea** (Four.)

17. Body pale, tadpole-like with thorax swollen; larvapods absent on abdominal segment 10; head dorsally prominent; antenna 4-segmented, broad, elongate, distal segment microscopic. Skeletonizer on undersurface of leaf in August, rare ..... **Caliroa** sp.

Body cylindrical, dark above spiracles, pale below; head red-brown with dark patch at apex and about the ocelli (Wong, 1954). July to September ..... **Empria multicolor** (Nort.)

18. Larvapods on abdominal segments 2 to 7 and 10; antenna flattened, 4-segmented 19

Larvapods on abdominal segments 2 to 8 and 10 (reduced on 8 in striped larvae of **Hemichroa**), antenna conical, 5-segmented 21

19. Anal protuberances present (Figure 6). 20

Anal protuberances absent; head brown, frons darker, pale line between ocelli above frons; antennal segment 1 minute, 2 and 3 complete rings, 4 peg-like; body waxy, brown but with light and dark areas laterally; midventral eversible gland prominent; epiproct brown-black. Abd. seg. 3 (Figure 21). August ..... **Nematus** sp. #2

20. Epiproct marking dark, triangular, pitted; anal protuberances dark; head brown with darker freckles, frons paler; body waxy, with brown dorsal and subdorsal area on thorax and first two abdominal segments; middorsal

brown stripe on abdominal segments 3 to 9; dark, broken, supraspiracular stripe on abdominal segments 2 to 8; brown markings below spiracles and on venter. Antenna (Figure 4). Abd. seg. 3 (Figure 22). June, August, and September ..... **Nematus erythrogaster** Nort.

Epiproct yellowish; anal protuberances pale; head dark brown with frons nearly black; body pale generally but with a segmental, dark brown, irregular patch, and elongate subspiracular sclerites from mesothorax to abdominal segment 7. (Younger larvae with dark areas dorsally.) Abd. seg. 3 (Figure 23). June to August ..... **Nematus umbratus** Thoms.

21. Head with black cap at apex; antennal segments complete 22

Head black with paler transverse line above frons; antennal segments 1 and 2 nearly obsolete; body pale with a dark prominent subdorsal stripe and two broken, dark, subspiracular stripes; 8 to 10 short, dark-tipped, pointed anal protuberances (Figure 8); larvapods on abdominal segment 8 reduced in size. Abd. seg. 3 (Figure 20). August and September ..... **Hemichroa crocea** (Four.)

22. Body pale green, usually covered with white flocculence; anal protuberances absent; head whitish with dark patch at apex. Abd. seg. 3 (Figure 24). June to September ..... **Eriocampa ovata** (Linn.)

Body pale with a wide dark supraspiracular band; a lateral row of fringe-like protuberances, smaller pairs dorsally, and two pairs posteriorly on anal shield (Figure 7); head orange-brown, dorsally prominent. Abd. seg. 3 (Figure 19). July and August ..... **Dimorphopteryx melanognathus** Roh.

Acknowledgments

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POSTEMBRYONIC DEVELOPMENT OF THE ENDOCRINE SYSTEM IN THE FEMALE HONEYBEE CASTES, *APIS MELLIFERA* L.

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Abstract

Histological evidences indicate secretory activity of the neurosecretory cells of the brain and the suboesophageal ganglion in the honeybee, *Apis mellifera* L., during the third instar larval stage.

In the queen larva there is an increase in size of the neurosecretory cells and corpora cardiaca, from 84 to 96 hours followed by a decrease. The corpora allata of queen larvae are always larger than those of workers of any age. In the prepupal period both the queen and the worker larva show an increase in the size of their neurosecretory cells and corpora cardiaca. Although the corpora cardiaca do not attain maximum size until late in the prepupal period they are probably functional as neurohemal organs in the fourth larval instar.

In the fourth and fifth larval instar the prothoracic glands and the oenocytes of the queen are larger than those of the worker. One day prior to pupation the prothoracic glands decrease in size; at pupation the oenocytes decrease in size. There may be an interrelationship in function between the prothoracic glands and the oenocytes.

The frontal ganglion of the stomatogastric nervous system shows histological evidence for a neurosecretory function.

Introduction

The insect endocrine system consists of four parts: neurosecretory cells in the brain (and other ganglia in the central nervous system), the corpora cardiaca, corpora allata and the prothoracic glands. The corpora allata and the prothoracic glands are the endocrine glands which produce the hormones controlling growth and development. These glands are activated and their activities coordinated by the neurosecretory cells in the brain. These relationships have been well reviewed by Wigglesworth (1964) and Gilbert (1964).

Canetti *et al* (1964) reported that 72-hour-old female honeybee larvae had no morphologically defined system for transport and storage of neurosecretory material. They questioned whether the brain was a source of activating hormone at this stage. Formigoni (1956) observed that in the female honeybee the neurosecretory cells of the pars intercerebralis differentiate early in larval life but do not function as neurosecretory cells until the corpora cardiaca are fully developed; he did not state the age of the material that he examined. L'Helias (1950) and Schaller (1950) found the honeybee larval corpora cardiaca to be rudimentary and questioned whether they played an important role in the very young larva. Endocrine control of the later stages of metamorphosis in the honeybee have been demonstrated by Schaller (1952) and Lukoschus (1955, 1956).

Oenocytes may also have an endocrine function. Wigglesworth (1965) has shown that in the silkworm the oenocytes are the first cells to show activity during the molt cycle but shown no such changes in abnormal strains of silkworms which fail to molt. Lukoschus (1955) found that oenocytes in the larvae of the female honeybee revealed changes toward metamorphosis and that they almost entirely disappeared before the imaginal molt. Locke (1969) suggested that the fine structure of oenocytes resembled the vertebrate steroid hormone synthesizing tissue and have a structure appropriate for the synthesis of the steroid ecdysone.

The endocrine system is closely associated anatomically and physiologically with both the central and dorsal sympathetic nervous system (Highnam 1964). The dorsal sympathetic nervous system, or stomatogastric nervous system, includes the frontal ganglion, the recurrent nerve, and several small ganglia on the dorsal side of the pharynx. Clarke and Langley (1963) rejected the idea that the frontal ganglionic cells of *Locusta migratoria* L. are neurosecretory. Although they contained stainable material there was no neurosecretory material in the axons, neither did the cells give evidence of any cyclical secretions. Hill, Mordue and Highnam (1966) have shown that the frontal ganglion has an essential role during growth and development of the locusts *Locusta migratoria* L. and *Schistocerca gregaria* L. In the absence of the frontal ganglion the cerebral neurosecretory system became inactive, and it was suggested that the failure was due to a general failure of protein synthesis as a result of interference with the synthesis of mRNA. Van der Kloot (1960) reported the presence of neurosecretory cells in the frontal ganglion of Lepidoptera.

In the honeybee, female dimorphism is not genetically controlled. It is controlled by the extrinsic factor of diet (Shuel and Dixon 1960). Dixon and Shuel have suggested that the dichotomy between castes may be the result of a nutritional balance mediated by the endocrine system. Lukoschus (1956) observed that quantity and quality of diet influenced the growth of the corpora allata and hence assumed an influence of diet on secretion by these glands. Canetti *et al* (1964) found that in the very early larval stages the corpora allata were the only endocrine organs which showed measurable caste differences. Mussbichler (1952) has suggested that protein deficiency may check development of the corpora allata and the prothoracic glands of the honeybee.

The purpose of this study was to investigate the development of the endocrine system of the two female honeybee castes throughout the entire developmental period prior to metamorphosis. Although something is known about all the glands at some stage of development (Ritcey 1969) there was a need of a comparative histological study to add completeness to our knowledge of these organs.

Materials and Methods

Experimental Animals

The honeybees were reared under natural conditions at the Department of Agriculture, University of Guelph. The larvae and pupae of the queen and worker were obtained from hives which were kept outside during the summer.

The uncapped larvae were weighed and their ages were determined by weight according to Stabe (1930). The start of the prepupal period was considered to be the time at which the cells were sealed by the nurse bees. The prepupal age was determined by the development of external features as reported by Myser (1954). The age of the pupae was determined by the color changes of their external features (Jay 1962).

Histological Technique

Whole larvae and pupae were punctured in the mid-region and were fixed in Bouin's solution. After three days in Bouin's solution, the larvae and pupae were bisected and the halves were dehydrated, cleared in xylene and embedded in paraffin. Sections 3 to 5μ in thickness were stained in Gabe's Paraldehyde fuchsin as modified by Ewen (1962).

The diameters of cells or nuclei in the different age groups were reported as the smallest and largest measurements. Different sections were examined to obtain the data from at least 10 specimens of each stage.

Results

Neurosecretory Cells

Neurosecretory cells are defined as a special type of nerve cells. In addition to their nervous function they are characterized by the production of a secretion with specific properties. Neurosecretory cells were identified by the staining properties of their secretory product. Generally it has been accepted that if the carrier substance was present the hormone was present (Highnam 1961).

For this investigation a distinction was made between neurosecretory cells and neuroblasts (Canetti *et al* 1964) because both types of cells contain stainable secretory products but only the neurosecretory cells have axons. In the brain and the suboesophageal ganglion, a cell with stainable secretory product was not considered a neurosecretory cell unless it had a well-defined axon and the diameter of the cell measured at least 8μ (Figures 1-5).

In the honeybee as in other insects the two fiber bundles (Figures 2, 3) which arise from the medial groups of neurosecretory cells decussate in the anterior part of the brain (Thomsen 1954). The axons of all the neurosecretory cells converge in a well-defined tract of fibers on either side of the brain. The fiber tracts curve in the antero-ventral region of the brain and proceed in a posterior direction lying very near to the ventral wall of the brain. The fiber tracts from the neurosecretory cells extend from the ventral part of the brain into the corpora cardiaca. Similar observations were made by Thomsen (1954) for adult Hymenoptera generally.

During the third larval instar the neurosecretory cells in both the queen and the worker could be distinguished from the neuroblasts in the brain and the suboesophageal ganglion. From 84 to 96 hours, in the fourth instar, there was an increase in the diameter of the neurosecretory cells in the queen but this increase in cell diameter was not observed in the worker (Table I). After 96 hours there

TABLE I. Comparisons of neurosecretory cell diameters in microns in the queen and worker

	Brain		Frontal ganglion	
Age	Queen	Worker	Queen	Worker
Larva (hours)				
54-84	10-13	8-12	9-12	8-10
84-96	10-16	8-13	10-14	8-10
96-	9-10	8-13	9-13	8-10
Prepupa* (days)				
1	12-13	9-13	12-14	10-12
2	12-16	10-14	12-14	11-12
3	13-20	12-17	13-14	12-14
4	13-20	12-20	13-14	12-14
Pupa (days)				
1	12-22	12-20	13-16	12-16
2	14-23	13-20	13-17	12-17
3	16-26		14-19	

*Queen prepupa aged by the morphology of the prepupal worker (Myser 1954)
Measurement in microns; error ± 0.5

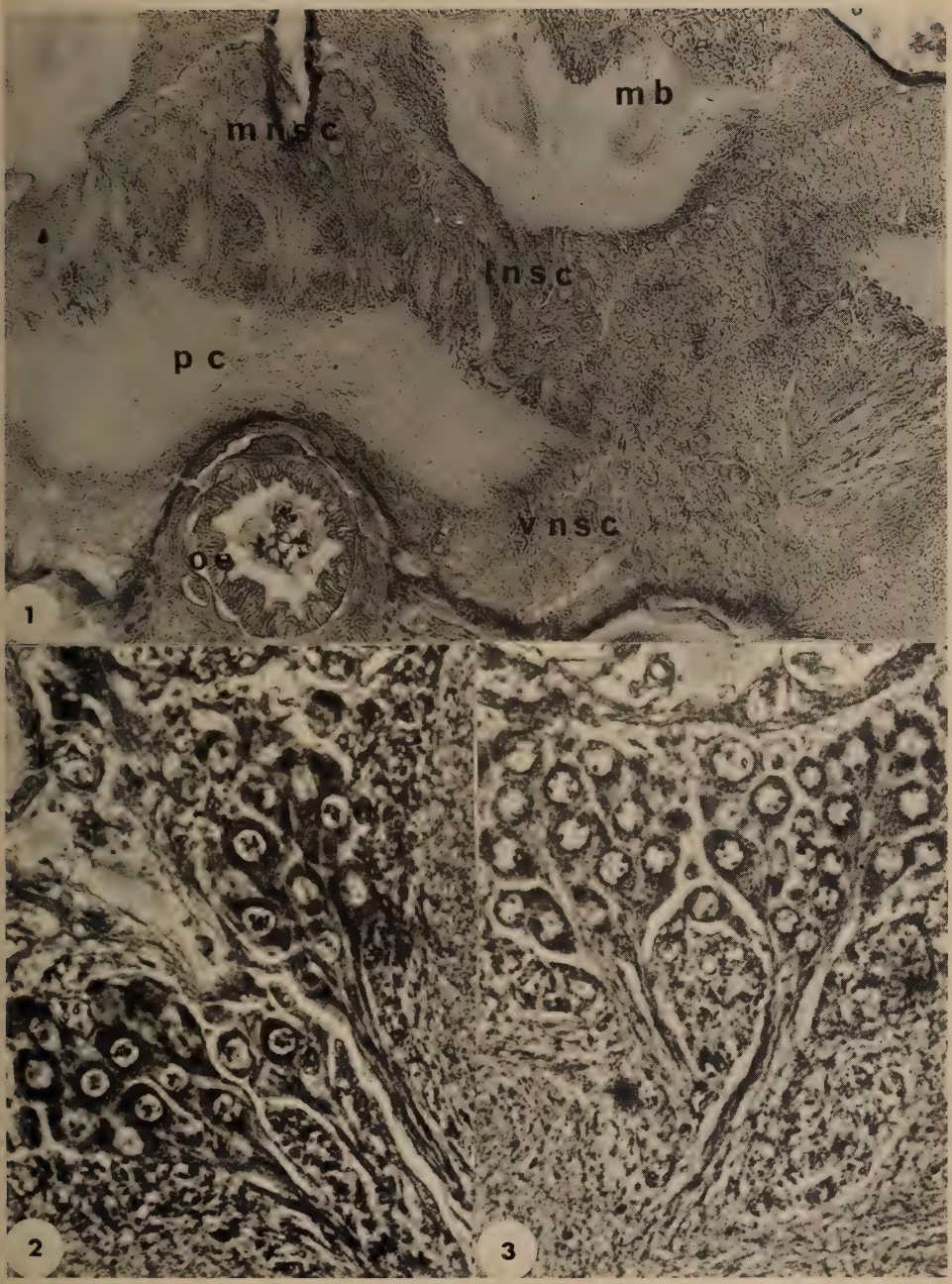

FIGURE 1. Section through the head region of female honeybee, late prepupal worker, 200×.

FIGURE 2. Two medial groups of neurosecretory cells in the pars intercerebralis, late prepupal queen. Phase contrast, 512×.

FIGURE 3. Medial groups of neurosecretory cells in the brain of a queen, late fourth instar. Note the nerve fibers or axons of the neurosecretory cells beginning to extend toward the opposite side of the brain. Phase contrast, 512×.

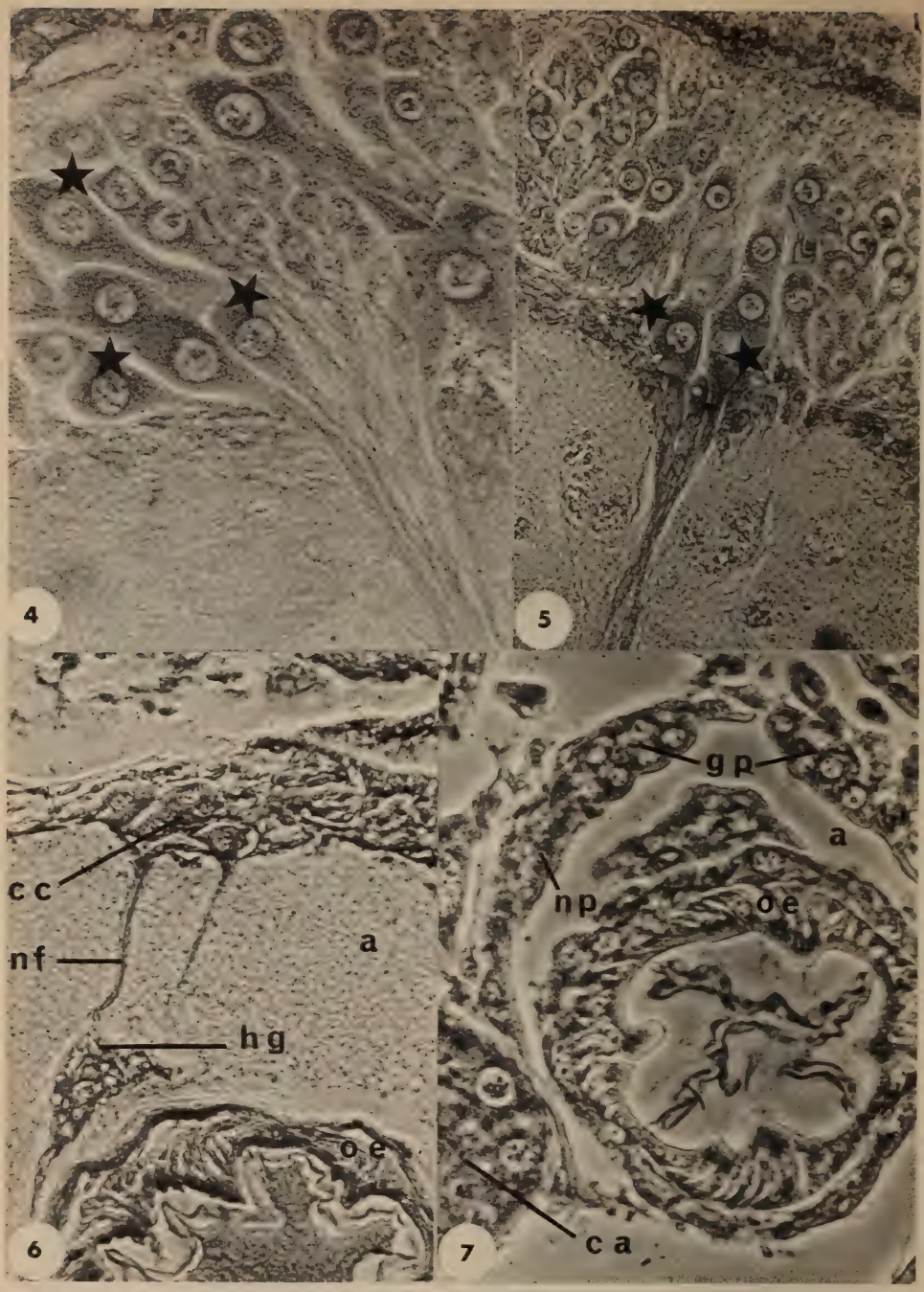

FIGURE 4. Neurosecretory cells in the suboesophageal ganglion, early queen pupa. Note the densely-stained secretory granules. Variation in size of the neurosecretory cells (*) within a group. 512×.

FIGURE 5. Neurosecretory cells in the suboesophageal ganglion, prepupal queen. Two prominent neurosecretory cells (*). 320×.

FIGURE 6. Nerve fibers from the hypocerebral ganglion to the glandular part of corpus cardiacum, early prepupal queen. Phase contrast. 512×.

FIGURE 7. Corpus cardiacum consisting of glandular part and nervous part of a queen larva, early third instar. Phase contrast, 512×.

was a decrease in the diameter of the neurosecretory cells followed by an increase in size during the prepupal period. In the worker larval brain during the second day of prepupal life, the neurosecretory cells have increased in size to almost that found in the queens. The maximum size of the neurosecretory cells was reached by both the queen and worker during the late prepupal and pupal period. Neurosecretory cells of the larva and pupa had approximately the same amount of neurosecretory product in proportion to the volume of the cell. In the cells studied the neurosecretory granules appeared to be of one type up to one-half micron in diameter.

Groups of neurosecretory cells were found in all parts of the brain, protocerebrum, deutocerebrum, and the tritocerebrum. Each group of 10 to 14 cells consisted of: two conspicuous large cells, two small cells and the remainder of an intermediate size (Figure 4). Throughout the larval and early pupal periods there were four prominent cells; one on either side of the medial section of the pars intercerebralis, and two on the ventral, midline of the suboesophageal ganglion (Figure 5). The protocerebrum contained three groups of cells: medial, lateral and ventral (Figure 1). The medial neurosecretory cells of the protocerebrum were paired groups of cells close to the midline in that region of the pars intercerebralis which connects the right and left halves of the protocerebrum (Figure 2). The lateral groups were situated dorsolaterally in the protocerebral lobe between the corpora pedunculata (mushroom body) and the optic lobes. The ventral groups were located ventral to the protocerebral lobe. The axonal tracts of the lateral groups ran downwards in the brain and united ventrally with those of the ventral groups before entering the nerve to the corpus cardiacum on the same side as their cell bodies. The groups of neurosecretory cells in the deutocerebrum and tritocerebrum extended their axons via the nervus corporis cardiaca to the corpus cardiacum of their side.

The circumoesophageal commissures were short in the honeybee and the suboesophageal ganglion appeared to be attached directly to the tritocerebrum. In some sections the groups of neurosecretory cells appeared to be continuous from the tritocerebrum to the suboesophageal ganglion. On closer examination the neurosecretory cells and their axons in the two regions were directed differently, dorsally for the tritocerebral cells and ventrally for suboesophageal cells. The suboesophageal ganglion consisted of median neuropile from which issue the three pairs of large nerves to the mouth region. Arranged dorsally, laterally and ventrally around the median neuropile were groups of neurosecretory cells whose axons extend into the neuropile.

Corpora Cardiaca

A pair of corpora cardiaca is situated behind the brain, intergrown laterally with the wall of the aorta. The corpora cardiaca are composed of two parts, a glandular part which occupies a position dorsal and lateral to a ventral, nervous part whose axons extend back to the neurosecretory cells of the brain (Figures 7, 8, 9). The nervus corporis allati enters the corpus allatum and is a direct continuation of the nervus corporis cardiaci. Not all the fibers of the nervus corporis cardiaci end in the corpus cardiacum, some continue laterally through the whole length of this organ and make an exit ventrally as the nervus corporis allati. This observation confirmed here for honeybee larvae was first reported for adult Hymenoptera by Thomsen (1954).

Within the glandular region of the corpora cardiaca there were large cells each with a cellular process. After 84 hours these cells contained stainable granules which measured up to one-half micron in diameter. Glial cells were also present.

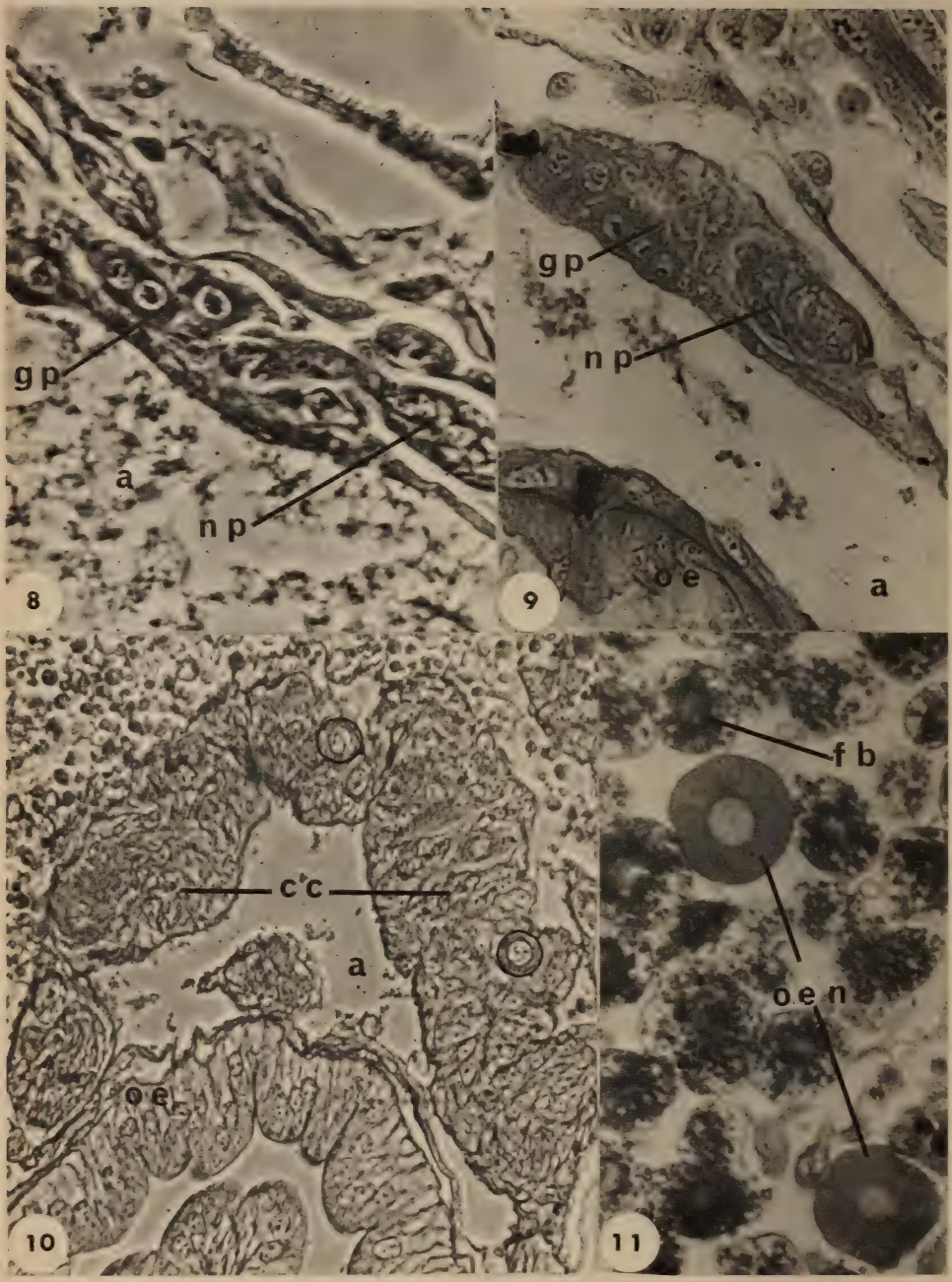

FIGURE 8. Corpus cardiacum, glandular part and nervous part of a queen larva, late fourth instar. Phase contrast, 512×.

FIGURE 9. Corpus cardiacum, glandular part and nervous part of a queen larva, late fourth instar. 500×.

FIGURE 10. Corpus cardiacum of a 3-day-old queen pupa. Note large granulated cells (O) of the glandular region. Phase contrast, 320×.

FIGURE 11. Oenocytes amongst fat-body cells in the abdominal region, late prepupal queen. 128×.

In the late fourth instar the diameter of the corpora cardiaca increased in size (Figures 8, 9) in queen larvae but not in the worker larva (Table III). During the 84 to 96 hour period in the queen this increase was due to the increase in cell size. After 96 hours the diameter of the corpora cardiaca decreased and not until the second day of the prepupal period did the diameter of the gland increase to that found in the late fourth larval instar. The corpora cardiaca continued to increase in size until the end of the prepupal or the beginning of the pupal period (Figure 10). The corpora cardiaca of the worker were always smaller than those of the queen. The corpora cardiaca of both the queen and the worker reached maximum size by the second or third day of the pupal period.

Corpora Allata

The changes in size and histology of these organs have been described by Canetti *et al* (1964) for the first few larval stages and by Pflugfelder (1958). These are not treated in detail here except to note for sake of comparison the size of these organs relative to the other glands (Table III). Canetti *et al* (1964) described a progressive increase in size particularly in the queen which was followed by the nuclear degeneration and pronounced reorganization in the late larval and prepupal stage. The corpora allata are always larger in size for any age in queens. In queens the corpora allata attain about maximum size early in the third larval stage. A slight decrease in size occurs during the prepupal stage.

Prothoracic Glands

The prothoracic glands consist of three pairs of loose strings of cells. One pair runs ventro-laterally to the esophagus and ends near the corpora allata; a second pair proceeds parallel to the esophagus and then dorsolaterally to the midgut; a third pair is attached to the epidermis near the anterior thoracic spiracles (Lukoschus 1956). The volume of the prothoracic glands is very difficult to measure. In most stages of development, the cell nucleus is uniformally ellipsoidal and was used for purposes of measurement. The regular relationship between nuclear size and cell volume suggests secretion periods for the prothoracic gland cells during development. Changes in volume of the nuclei were recorded as an expression of the variation in function of the gland cells during secretion.

In the larval and pupal periods large differences in the nuclear diameter were noted between the queen and worker prothoracic gland cells (Table II). Between the third day of larval life and the third day of the prepupal period the prothoracic gland nuclei of the queen larvae increased three- to fourfold in size (Figures 12, 13). In the late prepupal period the nuclei decreased in size in both the queen and worker. These observations agree with the observations of Lukoschus (1956).

Oenocytes

Oenocytes (Figure 11) are characterized by their dense and usually homogenous cytoplasm. The nucleus has an oval or round shape containing coarse dense chromatin granules. The cells may be free in the hemolymph or lodged amongst the fat-body cells giving the appearance of being an integral part of the fat body. Because oenocytes were irregular in outline the nuclei were measured for purposes of comparison during development.

Differences in nuclear size between castes appeared in the fourth larval period (Table II). From this period to late in the prepupal period there was a great increase in size of the queen oenocyte nuclei but only a slight increase in those of the worker.

Table II. Size comparisons of prothoracic gland cells and oenocytes of queen and worker honeybee, larvae and pupae

	Nuclear diameter of prothoracic gland cell in microns		Nuclear diameter of oenocyte in microns	
Age	Queen	Worker	Queen	Worker
Larva (hours)				
54-84	8-10	8-10	17-29	17-26
84-96	10-14	8-10	27-39	26-27
96-	13-18	9-11	35-39	27-29
Prepupa* (days)				
1	14-23	10-13	34-42	26-31
2	20-23	10-13	38-46	27-31
3	26-34	13-14	38-46	31-34
4	21-29	12-13	43-49	31-34
Pupa (days)				
1	13-26	10-13	31-39	27-31
2	13-20	10-12	29-34	27-31
3			29-30	23-27

*Queen prepupa aged by the morphology of the prepupal worker (Myser 1954)
Measurement in microns; error ± 0.5

In general, the oenocytes of the larvae are located in the posterior part of the thorax and the abdomen. Most of the oenocytes are situated ventrally near the silk glands, and their trachea occasionally attached to the tracheae. There was some indication of migration of oenocytes because in the pupae they were found in the anterior part of the thorax and in the head. The oenocytes occurred singly but sometimes in groups of two to five. There were no differences in numbers of oenocytes between the queen and worker larvae.

Stomatogastric Nervous System

1. *Frontal ganglion*: The frontal ganglion is situated above the esophagus and just in front of the brain. It is relatively large and somewhat pyriform in shape, its narrower end was directed caudally (Figure 14). The ganglion is ensheathed in a neural lamella within which the neurons are concentrated dorsally and laterally around a central neuropile. Its connection with the brain is by means of the frontal commissures which are rather stout bundles of fibers arising from the sides of the ganglion near its anterior end. From this point they run laterally and caudally to the anterior portions of the tritocerebrum. The frontal commissure connects the frontal ganglion with the tritocerebrum. From the anterior end of the frontal ganglion labral nerve fibers run to the tip of the labrum. The recurrent nerve proceeds along the dorsal surface of the oesophagus to the hypocerebral ganglion.

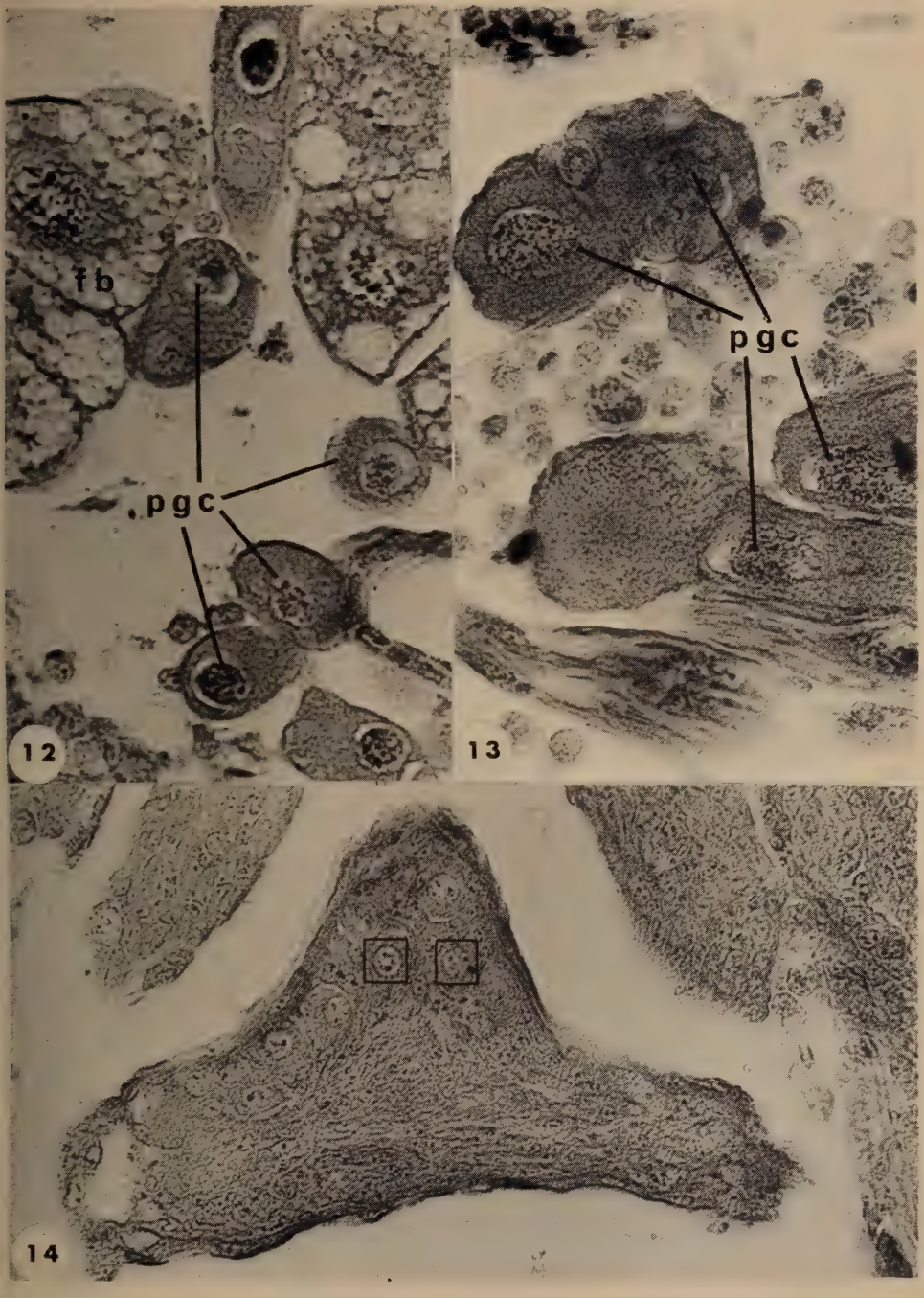

FIGURE 12. Prothoracic gland cells of a queen larva, late fourth instar. 500×.

FIGURE 13. Prothoracic gland cells of a queen larva, late prepupa. 500×.

FIGURE 14. Frontal ganglion, of the stomatogastric nervous system, late prepupal queen. Note the densely-stained neurosecretory granules in the cytoplasm of the cells (□). 500×.

TABLE III. Size comparisons of corpora cardiaca and corpora allata of queen and worker

	Diameter of corpora cardiaca in microns		Diameter of corpora allata in microns	
Age	Queen	Worker	Queen	Worker
Larva (hours)				
54-84	14-23	14-21	71-100	68-78
84-96	29-33	16-21	96-101	75-79
96-	23-26	20-21	98-111	78-83
Prepupa* (days)				
1	23-27	20-22	91-94	74-78
2	30-33	26-29	88-98	74-78
3	42-52	31-34	81-86	73-75
4	52	34-36	82-86	74-75
Pupa (days)				
1	52	39-40		
2	52	46-52		
3	52	52		

*Queen prepupa aged by the morphology of the prepupal worker (Myser 1954)
Measurement in microns; error ±0.5

In the frontal ganglion are 14 to 18 large nerve cells containing stainable granules (Figure 14). The diameter of these cells increased during development (Table I). The increase in diameter of these cells correlates with the range of increase for the neurosecretory cells in larval brains of comparable age. Less variation was seen in size of the frontal ganglionic cells of the precapped worker larvae compared with those of queen larvae (Table I).

2. *Hypocerebral Ganglion:* The frontal ganglion continues caudally as the recurrent nerve and appears to be in close contact with the dorsal wall of the esophagus near the hypocerebral ganglion just behind the brain. Nerve fibers connect the hypocerebral ganglion to the glandular part of the corpus cardiacum (Figure 6). From the hypocerebral ganglion the nerve bifurcates and each branch leads to a small cell mass. Further details were difficult to trace. Nelson (1924) observed that these cell masses are present only in the young larvae and that in the mature larvae their places are taken by branches of the nerve too small to be successfully traced.

Discussion and Conclusion

Except for the corpora allata, the endocrine system did not differ to any great extent between the queen and the worker prior to the third larval instar but differences appear toward the end of bipotent period.

Neurosecretory Cells

Canetti *et al* (1964) suggested that during the first few days of larval life prior to differentiation of neurosecretory cells neuroblasts might be the source of the neurosecretion material. Late in the third larval instar the presence of neurosecretory granules in the neurosecretory cells of the brain indicates that the neurosecretory cells are active. It might be possible that both the neuroblasts and neurosecretory cells are actively secreting: the former could provide a readily diffusible molecule.

In 84 to 96 hour queen larvae the increase in neurosecretory cell size may represent the synthesis and storage phase of neurosecretion. The decrease in volume of the cell early in the fifth larval instar may indicate the rapid release of the neurosecretion suggesting a phase of synthesis and release.

The neurosecretory cells of the worker contain less neurosecretory material. Variations in secretory activity are therefore less easily detected in worker larvae than in queen larvae.

In the prepupal period there was an increase in size of neurosecretory cells in both the queen and worker. There was no evidence for any cycles of synthesis and secretion.

The fact that neurosecretory cells differ with respect to size and location might suggest that there is a specific function for each cell type, especially in the pars intercerebralis which is known to regulate numerous processes hormonally (Etkin and Gilbert 1968). However, the variations in size may indicate that some of the cells are in a secretory stage while the other cells are in the storage stage.

The cells may differ both in rate of synthesis and rate of release. No one group of cells exhibited a cycle of accumulation and depletion of neurosecretory material distinct from the other groups of cells. At 96 hours the decrease in size of the neurosecretory cells of the queen occurred in all the groups and in all neurosecretory cells within a group. Electron microscopic studies may elucidate significant morphological differences between neurosecretory cells within a group. Differences may be noted in the synthetic activity of the nucleus, endoplasmic reticulum, Golgi apparatus, and the presence of the electron-dense and electron-lucent vesicles which are prominent organelles of neurosecretory cells. A knowledge of the function of the various neurosecretory cells and groups of cells is needed.

Corpora Cardiaca

Scharrer (1963) described the ultrastructure of the cell types within the corpora cardiaca of *Leucophaea madreae* (Fab.) establishing the presence of intrinsic secretory neurons, glial cells and their prolongations, and axons stemming from the nerve bodies within the brain. There has been no definite evidence for the presence of intrinsic secretory neurons in the corpora cardiaca of the female honeybee. Thomsen (1954) was unable to detect any cellular processes among the large cells in the corpora cardiaca of the adult Hymenoptera and assumed that these large cells were not nerve cells. In the female honeybee larvae there is evidence that the large cells are neurons and contain secretory granules. The granules were of the same size and had the same staining properties as the secretory granules in the neurosecretory cells of the brain. In the late fourth instar these cells increased in diameter and then decreased during the fifth instar. These differences in cell size are responsible for the variations in size of the corpora cardiaca (Table III).

During the third day of larval life, the fourth instar, the corpora cardiaca of the queen and the worker honeybee may be functional as a site of storage and

release for the neurosecretory product from the brain. After 84 hours of age the corpora cardiaca of the queen have neurosecretory granules in the neurons which are situated in the dorsal or glandular part of the organ. At this time the neurosecretory cells, especially in queen larvae, are also large and active.

Although the corpora cardiaca do not attain maximum size until late in the prepupal period they are probably functional as neurohemal organs in the fourth larval instar. The corpora cardiaca of the queen develop more quickly than those of the worker. This rate of growth parallels the increase in growth rate of the queen larvae, and lags somewhat behind the increase in size of the corpora allata.

Prothoracic Glands

The prothoracic glands produce a molting hormone which conditions the molting process and indirectly growth and morphogenesis. In the fifth larval instar of the queen and worker honeybee the prothoracic gland cells increase to maximum size and then toward pupation decrease in diameter. Therefore in the late prepupal period the decrease in volume indicates the end of secretion and the beginning of the degeneration of the prothoracic gland. The prothoracic gland hormone must be completely poured out at this time into the hemolymph.

The differences in size of the prothoracic gland cells of the two female castes may be highly significant. Lukoschus (1956) observed differences in the number of stages in cell division between the two castes, being greater in workers than in queens, presumably signifying a higher degree of ploidy. Merriam and Ris (1954) found nuclear differences between the female castes and made estimates on the degree of ploidy in several tissues. They concluded that dietary differences at certain stages of development "could induce fundamental nuclear differences". It is here suggested that the endocrine differences between castes could mediate dietary differences. The influence of the prothoracic glands on cell division and chromosome activity have been reviewed elsewhere (Gilbert 1964, Wigglesworth 1964). During this critical period, late in the fourth instar, differences in diet must be operating through an endocrine interaction involving particularly the prothoracic glands.

Oenocytes

Most authors are agreed that the oenocytes are organs of intermediary metabolism which discharge their secretion into the blood; but there is little to indicate what the nature of this secretion may be (Wigglesworth 1965). It is evident that the oenocytes bear some special relationship to growth, and perhaps to reproduction. Locke (1969) suggested that the morphology of the oenocytes in *Calpodes ethlius* Stoll was that of vertebrate cells engaged in steroid hormone synthesis. He pointed out that the oenocytes rather than the prothoracic glands could be the source of ecdysone and the stimulus for molting, or that the oenocytes may be elaborating the precursor of the molting hormone.

The prothoracic gland cells and the oenocytes of the female honeybee reach maximum size at approximately the same time in the prepupal period, but the prothoracic gland cells degenerate before the oenocytes (Table II). The oenocytes continue secreting until the molting process is complete but the prothoracic glands degenerate a day prior to pupal molt and the oenocytes become smaller, after the pupal molt.

Stomatogastric Nervous System

Clarke and Langley (1963) stated that the initiation of a growth and molting cycle in *Locusta migratoria* L. arose from changes in the gut at ecdysis. They proposed that the frontal ganglion plays a part in transmitting the nervous impulses from stretch receptors in the esophagus to the neurosecretory cells of the pars

intercerebralis which would thus correlate the release of the hormone with the intake of food. Fyg (1956) has found that the cocoon was essential to pupal development, the contact of the larval honeybee with the silk cocoon providing a necessary stimulus to the brain for initiation of pupation.

The frontal connectives join the labral nerve and it is possible that the cocoon stimulates the labral nerve. The nervous impulses may pass from the frontal ganglion via the frontal connectives to the brain and thus stimulate the medial neurosecretory cells. The frontal ganglion may also stimulate the corpora cardiaca via the recurrent nerve.

In insects, the neuropile of the frontal ganglion contains the endings of axons from the frontal ganglion connectives and recurrent nerve. In the frontal ganglion of the female honeybee the large cells are considered to be neurosecretory cells for the following reasons: (1) the stainable granules in the neurons of the frontal ganglion had the same variation in size and the same staining property as the secretory granules in the neurosecretory cells of the brain: (2) the neurons of the frontal ganglion increased at the same rate in the larval and early pupal period as neurosecretory cells in the brain except that no decrease in cell size was noted in the late precapped queen; (3) the neurons of the frontal ganglion were unipolar and pear-shaped like the neurosecretory cells in the brain. Our assumption that the frontal ganglion contains the neurosecretory cells substantiates the statement of Van der Kloot (1960), but is in disagreement with the view of Clarke and Langley (1963) who rejected the idea of the presence of neurosecretory cells in the frontal ganglion.

It was impossible to trace the axons and the termination of the neurosecretory cells of the frontal ganglion. There are different routes that the axons of the neurosecretory cells could follow. One route is from the frontal ganglion along the recurrent nerve to the hypocerebral ganglion, across to the glandular part of the corpora cardiaca, and terminating in the corpora cardiaca. Another route is through the hypocerebral ganglion with bifurcation along the gut and then division into smaller branches which may terminate in an endocrine organ. Usually neurosecretory cells terminate in a neurohemal organ but some authors have found that the neurosecretory neurons may innervate nonendocrine target organs (Fraser 1959, Maddrell 1966, Dogra 1967). The neurosecretory cells of the frontal ganglion may either innervate a neurohemal organ, the corpus cardiacum, or a nonendocrine target organ.

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Explanations of Figures

Legend:
a, aorta
ca, corpora allata
cc, corpus cardiacum
fb, fat-body cell
gp, glandular part
hg, hypocerebral ganglion
lnsc, lateral neurosecretory cells
mb, mushroom body
mnsc, medial neurosecretory cells
nf, nerve fiber
np, nervous part
oe, oesophagus
oen, oenocyte
pc, protocerebrum
pgc, prothoracic gland cell
vnsc, ventral neurosecretory cells

STUDIES ON PROTEINASES FROM SOME BLOOD-SUCKING INSECTS*

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Abstract

By use of synthetic substrates, trypsin and chymotrypsin have been demonstrated in the midguts of blood-fed *Aedes aegypti, Culex fatigans, Melophagus ovinus,* and *Pediculus humanus,* but not in those of *Cimex lectularius* or *Rhodnius prolixus.* The trypsin and chymotrypsin have been partially separated by Sephadex Gel filtration. Both enzymes are inhibited by phenylmethyl sulfonyl-fluoride and soybean trypsin inhibitor. The trypsins are inhibited by N-*a*-p-tosyl-lysine chloromethyl ketone but not by L-1-tosylamide-2-phenylethylchloromethyl ketone. The reverse is true for the chymotrypsins. *Cimex* and *Rhodnius* appear to have a high molecular weight proteinase with optimal activity at pH 5 in their midguts.

Most of the digestive proteinases found in insects have a pH optimum in the alkaline range. It has frequently been stated that these proteinases are comparable to mammalian trypsin. However, several other proteolytic enzymes are active in an alkaline medium (chymotrypsin, aminopeptidase, carboxypeptidase-A and carboxypeptidase-B) and the activity of these enzymes is not readily distinguishable from that of trypsin on the basis of the pH-activity curve alone. There are, however, several specific substrates and, in some cases, specific inhibitors which enable one to distinguish between the activities of the various alkaline proteinases.

This report presents data on the nature of the proteinases of *Aedes aegypti* (L.), *Culex fatigans* Weidemann, *Melophagus ovinus* (L.), *Pediculus humanus* L., *Cimex lectularius* L. and *Rhodnius prolixus* Stal. All of these species were maintained as laboratory colonies except *Melophagus ovinus,* specimens of which were collected from a local flock of sheep. The *Pediculus, Cimex,* and *Rhodnius* colonies were fed on rabbits, the *Culex* on chickens, and the *Aedes* on rats. The *Melophagus* were dissected 24 hours after collection from sheep, *Aedes, Culex,* and *Pediculus* were dissected 24 hours after a blood meal, and *Cimex* and *Rhodnius* were dissected 8 days after a blood meal. The midguts were homogenized in distilled water, centrifuged at 10,000 × g for 10 minutes at 4°C to remove insoluble debris, and then stored frozen until assayed.

Results and Discussion

1. *Effect of pH:* The proteinase activity in the midguts of *Aedes, Culex, Cimex,* and *Rhodnius* was studied at various pH's using denatured hemoglobin as a substrate (method of Gooding, 1966). The results (Figure 1) show that although the mosquitoes have most of their enzymatic activity in the alkaline range, the bugs have pH optima around pH 5; this is approximately the pH optimum of the cathepsins. The vertical scales are different on the figures for mosquitoes and bugs and there is, in fact, about 10 times as much enzyme activity in a mosquito's gut as there is in a bug's gut.

2. *Hydrolysis of Synthetic Substrates:* In order to further characterize the insect proteinases, assays were run to determine which synthetic substrates were hydrolyzed. The substrates used are specific for each of the alkaline proteinases: benzoyl-

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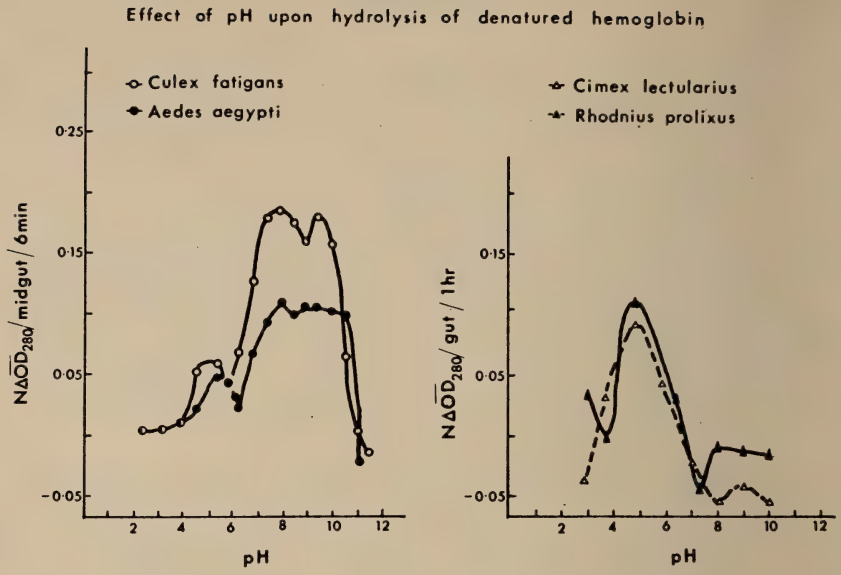

FIGURE 1. Effect of pH upon hydrolysis of denatured hemoglobin

L-arginine ethyl ester (BAEE) for trypsin (Schwert and Takenaka, 1955), tosyl-L-arginine methyl ester (TAME) for trypsin (Hummel, 1959), benzoyl-L-tyrosine ethyl ester (BTEE) for chymotrypsin (Hummel, 1959), hippuryl-L-phenylalanine (HPA) for carboxypeptidase-A (Folk and Gladner, 1960), hippuryl-L-arginine (HA) for carboxypeptidase-B (Folk *et al* 1960), and leucinamide (LA) for aminopeptidase (Binkley & Torres, 1960).

The results of assays done at pH 8 (Table I) indicate that both tryptic and chymotryptic activities occur in *Aedes, Culex, Melophagus,* and *Pediculus* but that these enzymes could not be demonstrated in *Cimex* or *Rhodnius.* At pH 7.5 HPA was slowly hydrolyzed by the *Rhodnius* midgut preparation (indicating the possible existence of carboxypeptidase-A in *Rhodnius*) but all other tests for carboxypeptidase-A, carboxypeptidase-B, and aminopeptidase were negative. At pH 5 the *Aedes* and *Culex* preparations hydrolyzed BAEE but not BTEE, while the reverse was true for *Cimex, Rhodnius,* and *Pediculus* midgut preparations.

3. *Sephadex Gel Filtration of Midgut Homogenates:* The possibility exists that the tryptic and chymotryptic activities observed in *Aedes, Culex, Pediculus,* and *Melophagus* were due, not to two different enzymes, but to a single enzyme with the catalytic properties of both (mammalian) trypsin and chymotrypsin. To investigate this possibility an attempt was made to separate the tryptic activity from the chymotryptic activity by passing midgut homogenates through a 90-cm long Sephadex G-75 column which was equilibrated with 0.05 M phosphate, 0.1 M KCl (pH 7.0) buffer. The $OD_{2\ 80}$ was read as an estimate of the protein concentrations and the tryptic and chymotryptic activity was determined on the eluted fractions. With mosquitoes the proteinases were well separated from the main protein peak, the chymotrypsin peak was slightly ahead of the trypsin peak and there was always much more trypsin than chymotrypsin (data for *Culex* are given in Figure 2). A similar elution profile was found with *Pediculus* (Figure 3), but the chymotryptic activity was greater than the tryptic activity. On the basis of the separation of the chymotryptic and the tryptic activity observed in *Aedes, Culex,* and *Pediculus,* it is concluded that the activities are due to two distinct enzymes.

TABLE 1. Hydrolysis of synthetic substrates by midgut homogenates. Hydrolysis is indicated by +, lack of hydrolysis by –, and a blank space indicates that the test was not performed.

		Synthetic Substrates Hdyrolized					
	pH5	pH8			pH7.5		
		BAEE	TAME	BTEE	HPA	HA	LA
Aedes aegypti	BAEE	+	+	+	—	—	—
Culex fatigans	BAEE	+	+	+	—	—	—
Melophagus ovinus			+	+	—	—	—
Cimex lectularis	BTEE	—		—			
Rhodnius prolixus	BTEE	—	—	—	+	—	—
Pediculus humanus	BTEE	+		+			

	Substrate	Enzyme
BAEE	Benzoyl-L-arginine ethyl ester	Trypsin
TAME	Tosyl-L-arginine methyl ester	Trypsin
BTEE	Benzoyl-L-tyrosine ethyl ester	Chymotrypsin
HPA	Hippuryl-L-phenylalanine	Carboxypeptidase A
HA	Hippuryl-L-arginine	Carboxypeptidase B
LA	Leucinamide	Aminopeptidase

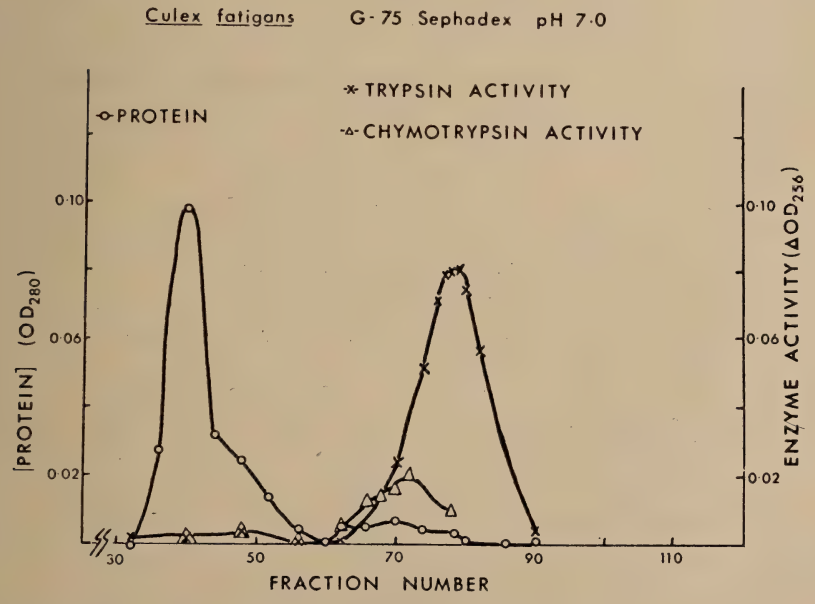

FIGURE 2. G-75 Sephadex Gel filtration of *Culex fatigans* midgut homogenate

Homogenates of *Cimex* and *Rhodnius* were also passed through a G-75 Sephadex column (as indicated above) and the fractions monitored for protein and the enzyme hydrolyzing BTEE at pH 5. The elution profiles for the two species were essentially the same (data for *Rhodnius* presented in Figure 4). The hydrolytic activity was associated with the high molecular weight proteins (M.Wt. $\geqslant$ 160,000) which came through in the "excluded volume" (fractions 50-60). The association

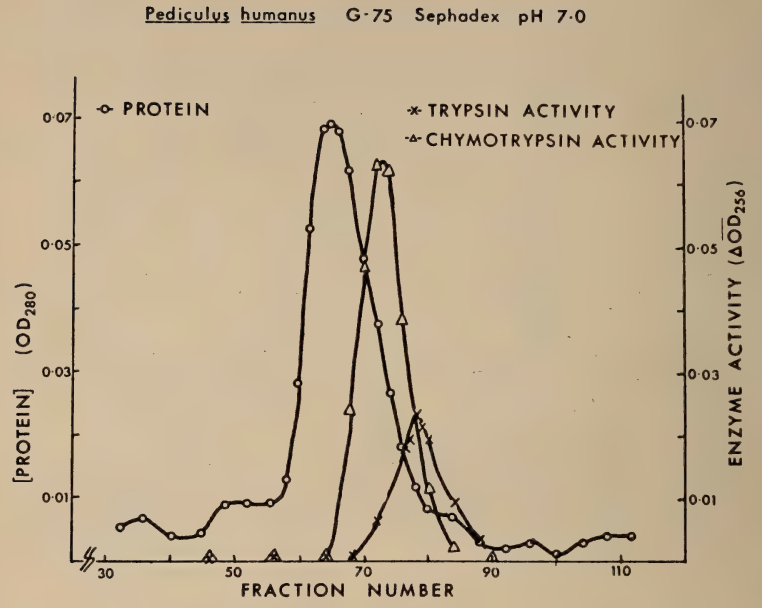

FIGURE 3. G-75 Sephadex Gel filtration of *Pediculus humanus* midgut homogenate

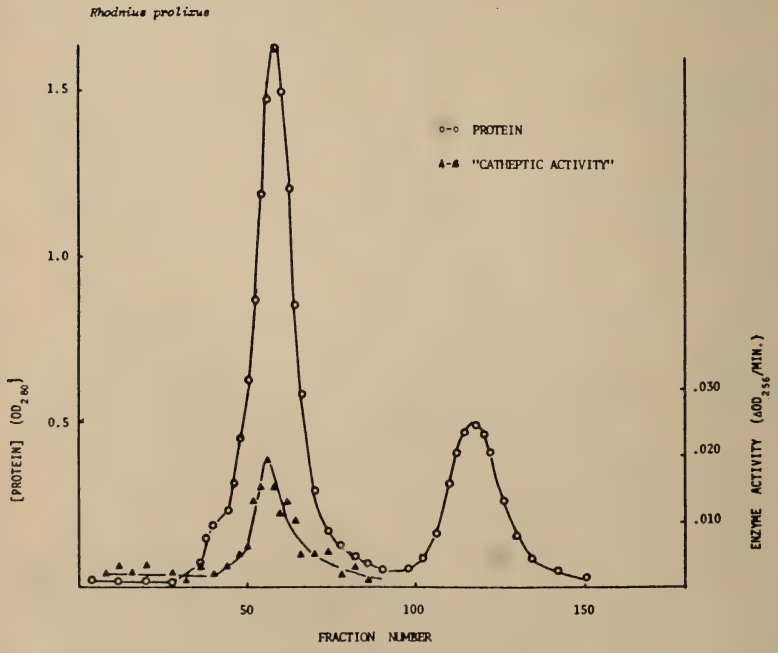

FIGURE 4. G-75 Sephadex Gel filtration of *Rhodnius prolixus* midgut homogenate

of the enzyme activity with the high molecular weight may be because of binding of a low molecular weight enzyme to other proteins or it may be that the enzyme is itself a high molecular weight protein. If it is the latter then the enzyme would be similar to mammalian cathepsin with respect to both pH optimum and molecular weight.

4. *Specific Inhibitors:* After material from the blood-sucking insects had been passed through the G-75 Sephadex, three enzymes (*Aedes* trypsin, *Culex* trypsin, and *Pediculus* chymotrypsin) were obtained in sufficient quantities to permit testing their susceptibility to specific inhibitors (see Baker, 1967; Farhney and Gold, 1963; Shaw, 1967). Since trypsin and chymotrypsin were not available from the same species of blood-sucking insect in sufficient quantities to permit a comparison of their susceptibilities to inhibitors, the trypsin and chymotrypsin of the ground beetle *Pterostichus melanarius* Illiger were prepared as indicated above and used for comparative purposes (Figure 6). The solution of enzyme was warmed to 30°C and an aliquot assayed, then a small amount of inhibitor was added and at intervals aliquots were assayed (Figures 5, 6). Phenylmethyl sulfonylfluoride (PMSF, an inhibitor of mammalian trypsin and chymotrypsin) dissolved in 2-propanol (final concentration of 10^{-3} M PMSF, 5% 2-propanol) was an effective inhibitor of both trypsin and chymotrypsin regardless of the source of these enzymes. L-1-tosyl-L-lysine chloromethyl ketone (TLCK, a mammalian trypsin inhibitor) inhibited *Aedes, Culex,* and *Pterostichus* trypsin (at final TLCK concentration of 10^{-3} M) but not *Pediculus* or *Pterostichus* chymotrypsin. N-α-p-tosylamide-2-phenylethylchloromethyl ketone (TPCK, an inhibitor of mammalian chymotrypsin) did not affect the trypsin from any species but did inhibit the *Pediculus* and *Pterostichus* chymotrypsin (at a final concentration of 10^{-3} M TPCK,

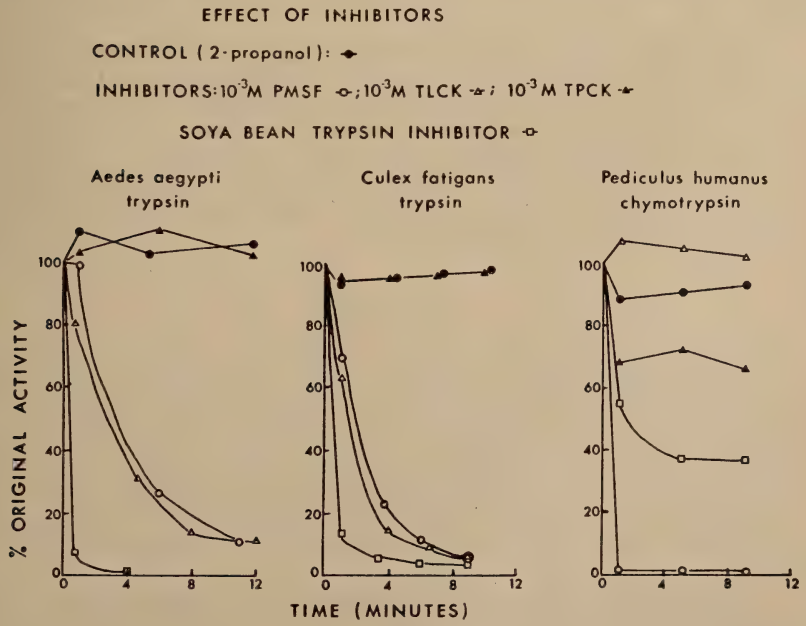

FIGURE 5. The effect of inhibitors on *Aedes* trypsin, *Culex* trypsin, and *Pediculus* chymotrypsin

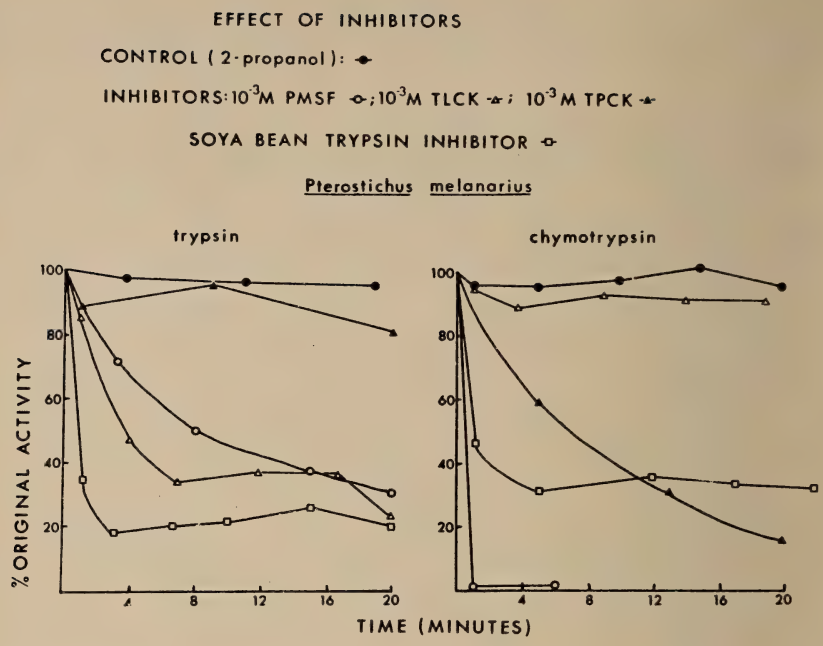

FIGURE 6. The effect of inhibitors on *Pterostichus* trypsin and chymotrypsin

2% methanol). Soybean trypsin inhibitor (which has little or no effect upon bovine α-chymotrypsin) at 50 μ g/ml inhibited the insect trypsins and chymotrypsins.

The inhibitors PMSF, TLCK, and TPCK are active-site-directed irreversible-inhibitors which react with specific amino acid residues in the enzyme. On the assumption that these inhibitors attack the same residues in the insect enzymes as they do in the vertebrate enzymes, it appears that the active centers of insect trypsin and chymotrypsin contain both serine (inhibition by PMSF) and histidine (inhibition by TLCK and TPCK). The inhibition of insect chymotrypsin by soybean trypsin inhibitor indicates that the insect enzyme differs in some as yet unknown way from bovine α-chymotrypsin.

Conclusions

On the basis of hydrolysis of synthetic substrates it appears that *Aedes aegypti, Culex fatigans, Melophagus ovinus,* and *Pediculus humanus* have both a trypsin and a chymotrypsin in their midguts during the digestion of a blood meal. The susceptibility of these enzymes to active-site-directed-irreversible-inhibitors is similar to the corresponding mammalian enzymes and indicates that (like the mammalian enzymes) the insect trypsin and chymotrypsin probably have serine and histidine residues at their active centers. The chymotrypsin from *Pediculus* differs from bovine α-chymotrypsin with respect to susceptibility to inhibition by soybean trypsin inhibitor.

Neither trypsin nor chymotrypsin appears to be present in the midguts of *Cimex lectularius* or *Rhodnius prolixus,* but a high molecular weight proteinase with optimal activity at pH 5 was present.

Acknowledgments

I am happy to acknowledge the competent technical assistance of Mr. A. C. Cheung during part of this study, and to thank Dr. B. Hocking and Dr. B. S. Heming, Department of Entomology, University of Alberta, for their helpful comments on the manuscript.

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A KEY TO COMMON LEPIDOPTEROUS LARVAE FEEDING ON ASPEN FOLIAGE IN ONTARIO

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Abstract

A key to larvae of 20 species in Arctiidae, Lasiocampidae, Noctuidae, Notodontidae, Nymphalidae, Gelechiidae, Oecophoridae, Olethreutidae, Pyralidae, and Tortricidae which are defoliators of aspen is presented.

Introduction

The Forest Insect and Disease Survey in Ontario has assessed insect populations, and their damage to trees, for over 20 years. Thousands of insect samples, mainly of larval stages and from all species of trees and shrubs, have been identified annually. Analysis of records from aspen, *Populus tremuloides* Michx. and *P. grandidentata* Michx., show that the main defoliators of these tree species have been in the order Lepidoptera. The following key was prepared to facilitate the identification of the more common lepidopterous larvae feeding on aspen foliage. Numerous minor and all non-defoliating species have been omitted in the interest of simplicity.

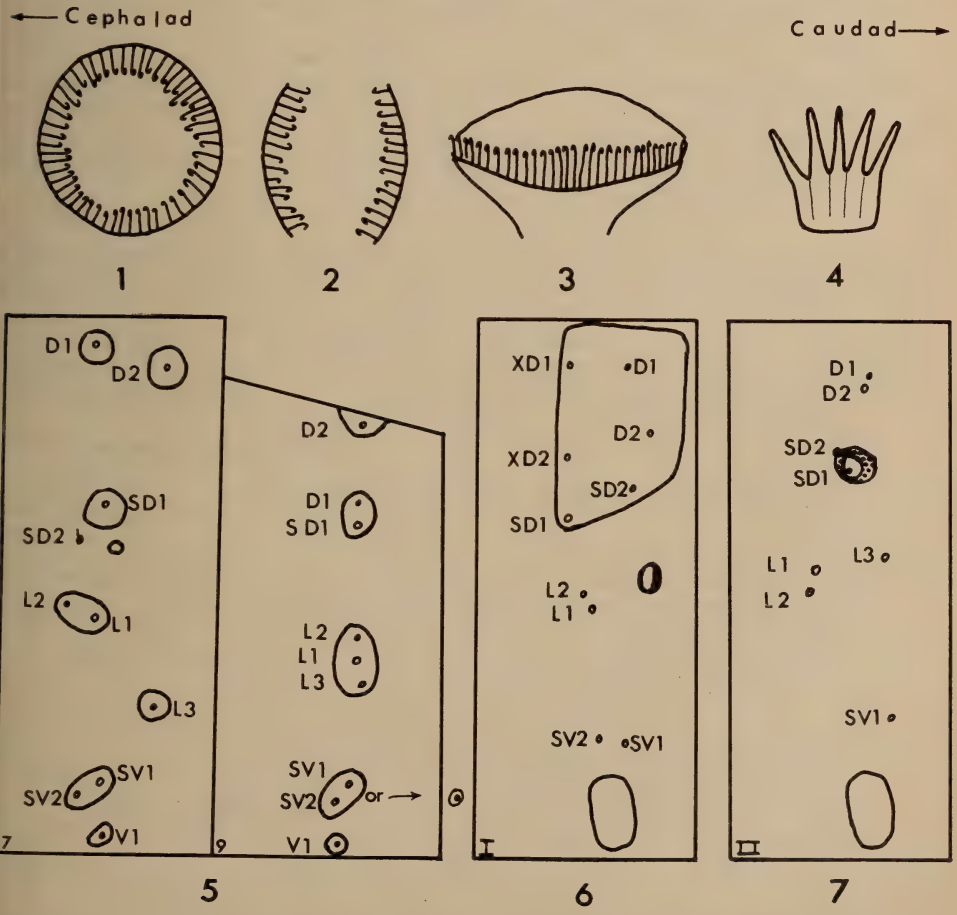
The families represented are Arctiidae, Lasiocampidae, Noctuidae, Notodontidae, and Nymphalidae in the Macrolepidoptera; and Gelechiidae, Oecophoridae, Olethreutidae, Pyralidae, and Tortricidae in the Microlepidoptera. Morphological information on the larvae was drawn from literature and from the examination of insect material in Survey reference collections. In addition to specific citations appearing in the key, general sources of information were Peterson (1948), Fracker (1915), Crumb (1956), Craighead (1949), and Forbes (1923, 1948, 1954, 1960). Seasonal occurrence of larval stages was obtained from Survey records.

Key to Advanced Larvae

1. Proleg crochets arranged in a circle (Figure 1) or as a pair of transverse arcs (Figure 2). (Microlepidoptera) 2
   Proleg crochets in a longitudinal series (Figure 3). (Macrolepidoptera) 13
2. Proleg crochets arranged in a circle 3
   Proleg crochets arranged as a pair of transverse arcs 12
3. Prothorax with L group of setae bisetose (Figure 6); gregarious in webbed or loosely tied leaves, July to September 4
   Prothorax with L group of setae trisetose; single larvae in leaf rolls or between two tied leaves 5
4. A brown ring with whitish center around SD1 seta on mesothorax and abdominal segment 8 (Figure 7); body dusky magenta above spiracles, paler below ..... **Meroptera pravella** Grt.
   Brown ring absent on mesothorax but present on abdominal segment 8; dorsum yellowish with darker lines, venter paler ..... **Tetralopha aplastella** Hlst.
5. Body dusky greenish black or dark brown; pinacula, head, shields, and legs brown to black; anal comb present (Figure 4) 6

Body cream to green; sclerites dark or pale; anal comb present or absent 7

6. Body dark brown; slender, active larva; spiracle on abdominal segments 2 or 3 times its diameter from SD1 seta; anal shield tapered posteriorly (MacKay, 1959) Leaf roller May to July ..... **Badebecia urticana** Hbn.
   Body dusky green or blackish; spiracle on abdominal segments 1 to 1.5 times its diameter from SD1 seta; anal shield rounded posteriorly (MacKay, 1962a). Larva in a roomy shelter between two leaves or in leaf rolls in May to July ..... **Choristoneura conflictana** Wlk.
7. Pinacula brown-black, conspicuous; head, legs, and shields black 8
   Pinacula light brown or paler 9
8. Body cream-colored; two SV setae on abdominal segment 7 (MacKay, 1959). Leaf roller May to July ..... **Sciaphila duplex** Wlshm.
   Body gray-green; usually three SV setae on abdominal segment 7. (See also couplet 6.) ..... occasional larva of **Choristoneura conflictana** Wlk.



FIGURES 1-7. Larval characters 1 and 2, proleg crochets of Microlepidoptera, ventral aspect; 3, proleg crochets of Macrolepidoptera, lateroventral aspect; 4, Tortricoid anal comb; 5, *Pseudexentera oregonana* Wlshm., setal map of abdominal segments 7 and 9; 6, *Tetralopha aplastella* Hlst., setal map of prothorax; 7, *Meroptera pravella* Grt., setal map of mesothorax.

9. Anal comb absent or minute 10
Anal comb present and well developed 11

10. Spiracles oval and conspicuous, on prothorax with wide black rim, on other segments the rim narrow anteriorly and wide posteriorly; body cream-colored with a pinkish tinge, or pale green, flattened dorsoventrally; head red-brown. Feeding between two leaves tied together in July to September ..... **Psilocorsis fletcherella** Gibs.
Spiracles more or less circular, inconspicuous; body cream-gray, spinules dark and distinct; thoracic shield yellowish, usually bordered posteriorly and laterally with brown; thoracic legs dark; head yellow-brown with dark shading (MacKay, 1962b). Leaf roller in May and June .... **Epinotia solandriana** Linn.

11. Body cream-gray; thoracic shield pale with dark posterior edge; thoracic legs with dark sclerites; head usually light brown with darker pattern; two SV setae on abdominal segment 7 (Figure 5); setae D1 and SD1 of abdominal segment 9 on same pinaculum (Figure 5) (MacKay, 1962a, 1965). Leaf roller in May and June .... **Pseudexentera oregonana** Wlshm.
Body green; color of sclerotized areas highly variable; head yellow-brown to red or black; thoracic shield blackish, or pale with dark lateral and posterior areas; thoracic legs usually black; three SV setae on abdominal segment 7; setae D1 and SD1 of abdominal segment 9 on separate pinacula (MacKay, 1962a). Leaf roller May to July .... **Choristoneura rosaceana** Harr. or **Archips argyrospilus** Wlk.

12. Head yellowish with dark bars or triangular areas posteriorly; thoracic shield yellowish, often with dark areas; body cream with dark pinacula; thoracic legs dark. Leaf roller in May to July .... **Anacampsis (=Compsolechia) niveopulvella** Cham.
Head usually dark, if yellowish then with solid dark area posteriorly; thoracic shield usually dark; otherwise similar to **A. niveopulvella** and not readily separated from it. Leaf roller in May to July .... **Anacampsis innocuella** Zell.

13. Larva smooth without spines or long supernumerary hair 14
Larva humped, spiny, hairy, or with at least some fine long supernumerary hairs 16

14. Head pale yellow, unmarked; body pale yellow-green; a faint middorsal line and slender subdorsal and spiracular white lines; spiracles with white centers and yellow rims. Larva solitary between two leaves tied with silk in June and July ..... **Enargia decolor** Wlk.
Head white with conspicuous black lines, or entirely black 15

15. Head creamy white with a heavy black vertical dorsolateral band; body whitish green with white middorsal line and narrower lateral white lines; spiracles with white centers and dark rims; thoracic legs black or black-tipped. May to July ..... **Ipimorpha pleonectusa** Grt.
Head blackish; body gray-black dorsally with single fine white middorsal and subdorsal lines; subspiracular line white; venter pale. June to August ..... **Xylomyges dolosa** Grt.

16. Body with a conspicuous middorsal row of white segmental "keyhole" markings; body blue-gray generally with black markings and single, narrow, yellow subdorsal, and supraspiracular lines; head and body with pale, fine hair. May and June ..... **Malacosoma disstria** Hbn.
White "keyhole" markings absent 17

17. Blackish larva covered with long, stiff-branched spines and the body thickly sprinkled with whitish dots; a reddish middorsal spot on most segments. Colonial feeder in June to September ..... **Nymphalis antiopa** Linn.
Body not covered with long branched spines 18

18. Abdominal segment 1 with a red hump; body yellowish with narrow reddish-black and white lines, and short black spines; head red (black in early stages). Colonial feeder in July to September ..... **Schizura concinna** J. E. Smith.
Body with a broad, dusky, dorsal band; lateral areas pale with various markings; body covered with long whitish to brownish hairs which arise from black or orange warts. Head and legs black. A webmaker in July to September, late instars wandering ..... **Hyphantria cunea** Dru.

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FURROW APPLICATIONS OF VARIOUS INSECTICIDE-FUNGICIDE COMBINATIONS FOR CONTROL OF ONION MAGGOT AND ONION SMUT IN ONIONS GROWN FROM SEED IN ONTARIO

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Abstract

Field tests demonstrated that a granular application in the planting furrow with VC-13, ethion, carbofuran, N-2596, chlorfenvinphos, dyfonate, Bayer 37289, Dasanit® or pp 211 provided good control of the onion maggot for the entire growing season. Diazinon was less effective and bromophos and C-10015 did not provide adequate control. Thiram, when incorporated in the pesticidal granule, provided good control of onion smut but extra thiram as a seed dressing or added with the seed improved control. Polygram was as effective as thiram when used in the pesticide granule.

Introduction

The onion maggot, *Hylemya antiqua* (Meig.), is a serious pest of onions throughout North America. Prior to the introduction of modern pesticides, some degree of control was possible by spraying with Bordeaux-oil mixtures or with drench treatments of mercuric chloride. The cyclodiene insecticides proved highly toxic to the larvae of this insect and beginning in the late 1940's, these materials were used as furrow, drench or foliage applications with excellent results. This phase of control is reviewed by Finlayson *et al,* 1959. Resistance to aldrin had developed in Ontario by 1958 (MacNay, 1958), and a general resistance to the cyclodiene pesticides developed in other major onion-growing areas (Ellington and Rawlins, 1961; Guyer and Wells, 1959; Howitt, 1958; Peterson *et al,* 1963) in the late 1950's. Phosphate insecticides have been widely used for onion maggot control since that time (Rawlins and Gonzalez, 1966).

In Ontario a large acreage of onions is grown in the Holland-Bradford Marsh south of Lake Simcoe. Here the maggot became resistant to the cyclodiene pesticides by 1958 and since that time control has been possible with furrow, granular, or drench applications of phosphate insecticides. Grower practice in this area is almost entirely a furrow treatment with a granular phosphate (diazinon, ethion or VC-13) followed by foliar applications with diazinon and/or DDT when adults are in flight. This high degree of dependence on a limited number of pesticides prompted the testing of new compounds to learn what insecticides might provide adequate control should the insect develop resistance to the chemicals now in use.

Materials and Methods

Onions for field tests were planted in the Bradford Marsh on May 6, 1969. Two series of tests were conducted with 14 treatments included in each test. In all treatments, four replicates were included in a randomized block design and each replicate consisted of two rows, 15 feet long. Rows were spaced 16 inches apart and replicates were separated by 3 feet of unplanted area. The onion variety "Autumn Spice" was used and the seeding rate was approximately 300 seeds per

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15-foot row (4 pounds per acre). This seeding rate was maintained by first counting several seed lots from a given volume of seed and then using a measure that consistently contained about 300 seeds. The insecticides used were mostly granular formulations, although a few wettable powder formulations were also tested as well as three seed treatments. With either the granular or wettable powder formulation, the amount of formulation needed for 15 feet of row (based on 32,000 lineal feet of row per acre) was weighed prior to planting and placed in a small coin envelope. Planting was done with a hand-push V-belt seeder with the belt travel geared to the front wheel of the seeder. This was geared to rotate approximately one-half of its length in 15 feet of ground travel. Thus materials placed on the upper belt surface were all delivered in the row length provided. The seeder shoe opened a furrow about 1 inch in depth, seeds and pesticides fell into this furrow, and a press wheel provided coverage. The seed bed was rich muck soil and moisture content was ideal for planting. In the planting operation, the seed was distributed by hand on the planter belt, the insecticide formulation was similarly distributed on the belt and thus seed and pesticide fell together into the seed furrow. A fungicide for smut control (thiram in most cases) was included in some form in all treatments, except one check and two experimental compounds. In those treatments where a fungicide could be obtained in combination with the insecticide in the pesticide granule, no further fungicide was used. Where such combination granule was not available, the fungicide thiram was used as a seed coating (1 pound thiram 75% WP per 4 pounds onion seed).

Treatment efficacy was evaluated on the basis of 20 feet of row in each plot, 10 feet from the mid-portion of each of the 15-foot rows. This evaluation consisted of an emergence count (May 30), a second count when maggot attack had killed a portion of the seedlings in unprotected plots (June 17), a third count when maggot activity had ceased (July 16) and a yield evaluation at normal harvest time (October 3).

An attempt was made to use thiram at the recommended rate of 2 pounds per acre but in some treatments this rate was changed to evaluate the insecticide-fungicide ratio or to explore different rates in relation to smut control.

Materials in these tests included the following:

Granular formulation; insecticide and fungicide

VC-13	(0, 0-Diethyl 0-2, 4-dichlorophenyl 5% + Thiram 10% phosphorothioate)
Ethion	5% + Thiram 5%
Bromophos	2.6% + Thiram 8.8%
Carbofuran	5% + Thiram 5%
C-10015	(2-(4, 5-dimethyl-1, 3-dioxolane- 2-yl)-phenyl-N-methyl-carbamate) 5% + Thiram 8.8%
Chlorfenvinphos	10% + Thiram 20%
Dyfonate	(O-ethyl-S-phenyl-ethylphosphonodithioate) 5% + Thiram 10%
Carbofuran	5% + Polyram 5%

Granular formulation; insecticide only

Bromophos	3%
C-10015	6%
Birlane®	10%
N-2596	(Stauffer Chemical Company) 10%
Dasanit®	(0, 0-Diethyl 0-(p-(methylsulfinyl) phenyl) phosphorothioate 15%
Bayer 37289	(0-ethyl 0-2-4, 5-trichlorophenyl ethylphosphonothioate 15%
Diazinon	5%
PP 211	(Imperial Chemical Industries Limited) 5%

Seed treatment (WP) formulations

Diazinon 15% + Captan 30%
PP 211 25% + Captan 37.5% (Imperial Chemical Industries Limited)
PP 511 25% + Captan 37.5% (Imperial Chemical Industries Limited)
Thiram 75%

Results

In both tests the incidence of plant loss in unprotected plantings was high (Tables I and II). Plantings that contained neither fungicide nor insecticide (treatment No. 14) were almost completely destroyed by a combination of onion smut and maggot (Figure 1). Where only a fungicide was used (treatment No. 13), most of the plants were eliminated by maggot attack.

FIGURE 1. Treated (left and right) vs not treated plots of onion. Photo on August 20, 1969

In test No. 1 (Table I) C-10015 was completely ineffective in maggot control and neither Bromophos in granular form nor diazinon in a seed dressing provided satisfactory control. Each of the other insecticides in combination with the fungicide provided good maggot control with no statistically significant differences in stand of undamaged plants in any of the counts taken. In combination with carbofuran, polyram and thiram performed equally in smut control (Table I, No. 4 and 5), but there is some evidence that the use of Thiram-treated seed with the granular furrow application (Table 1, No. 3 versus No. 5) provided slightly better protection. Comparable yields were obtained in plots protected from maggot damage with VC-13, ethion, carbofuran, chlorfenvinphos or dyfonate. Plots treated with pp 211 or pp 511 yielded slightly less.

TABLE I. Stand of onion plants on three dates after planting, % onion smut in selected plots on August 7, and yield with the indicated treatment — Bradford Marsh, 1969

Number	Treatment and Formulation		Rate—lbs formulation per acre	Stand on indicated date[1]			Yield	%
				May 30	June 17	July 16	Lbs[1]	Smut[2]
1	VC-13	—Thiram (5%-10%) G	20	372	349	252	22.5	—
2	Ethion	—Thiram (5%-5%) G	40	342	328	241	25.4	—
3	Carbofuran	—Thiram (5%-5%) G[3]	20	332	281	268	26.7	4.8
4	Carbofuran	—Polyram (5%-5%) G	20	353	294	220	25.6	7.7
5	Carbofuran	—Thiram (5%-5%) G	20	383	277	222	25.3	9.0
6	Bromophos	—Thiram (2.6%-8.8%) G	38	356	224	132	20.1	—
7	C-10015	—Thiram (5.3%-8.8%) G	19	378	226	51	5.4	—
8	Chlorfenvinphos	—Thiram (10%-20%) G	10	340	326	248	25.2	—
9	Dyfonate	—Thiram (5%-5%) G	20	389	318	302	26.2	—
10	Diazinon	—Captan (15%-30%) WP	7 oz/lb seed	383	282	185	17.4	—
11	PP 211	—Captan (25%-37.5%) WP	5 oz/lb seed	392	322	240	23.8	—
12	PP 511	—Captan (25%-37.5%) WP	5 oz/lb seed	323	304	231	21.9	—
13	Thiram	— 75% WP[3]	4 oz/lb seed	310	208	82	9.2	—
14	None	— — —	—	369	207	10	0.5	—
	LSD	— 5% —	—	NSD	85	58	3.8	4.4

[1]Mean of four replications — total in 20 feet of row
[2]% of plants showing symptoms of onion smut on August 7 — no record in these plots
[3]Seed treated with Thiram (4oz/lb seed) — untreated seed in other plots

TABLE II. Stand of onion plants on three dates after planting, % onion smut in selected plots, and yield with the indicated treatment — Bradford Marsh, 1969

Number	Treatment and Formulation			Rate—lbs formulation per acre	Stand on indicated date[1]			Yield	%
					May 30	June 17	July 16	Lbs[1]	Smut[2]
1	Bromophos	3% G	— TS[3]	3.3	277	216	127	18.6	—
2	C-10015	6% G	— TS	16.6	271	181	84	13.2	—
3	Chlorfenvinphos	10% G	— TS	10	278	240	202	26.0	—
4	N-2596	10% G	— TS	10	259	212	202	28.0	—
5	Bayer 37289	15% G	— TS	6.6	266	259	230	28.0	—
6	Diazinon	5% G	— TS	20	268	238	142	21.6	—
7	Dasanit®	15% G	— TS	13.2	306	263	242	29.9	—
8	Dasanit®	15% G	— TS	9.9	279	253	236	27.2	—
9	Dasanit®	15% G	— TS	6.6	296	232	241	29.7	8.3
10	Dasanit®	15% G + Thiram 75%	NTS[4]	6.6 + 10.00	296	264	260	25.9	1.1
11	Dasanit®	15% G + Thiram 75%	NTS[4]	6.6 + 20.00	311	302	286	28.5	1.1
12	PP 211	5% G	— TS	20.0	263	214	211	33.4	—
13	Thiram	75% WP	— TS	4 oz/lb seed	275	157	58	10.8	—
14	None	—	— NTS[4]	—	280	194	34	4.7	—
	LSD	5%	— —	—	NSD	51	84	6.8	4.5

[1]Mean of four replications — total in 20 feet of row
[2]% of plants showing symptoms of onion smut on August 7 — no record in these plots
[3]TS — Treated seed — Thiram 4 oz/lb seed
[4]NTS — Seed not treated

In test No. 2, additional new insecticides were tested, but since these were not available in granular forms in combination with a fungicide, fungicide-treated seed was used to permit comparable evaluation. As in test No. 1, C-10015 did not provide adequate maggot control at the 1 pound per acre dosage. In the May 30 and June 17 counts, stands in plots receiving Bromophos or diazinon were good but neither of these materials protected the plants from maggot attack to July 16 (Table II). Chlorfenvinphos, N-2596, Bayer 37289, Dasanit® and pp 211 each provided good maggot control as indicated by stand counts and by yield. Varying the treatment rate of Dasanit® from 1.0 to 1.5 or 2.0 pounds active per acre did not significantly affect either maggot control or yield. The addition of large amounts of thiram added on the planter belt when seeding (No 10 and 11) improved the control of onion smut over that obtained with thiram-treated seed. Although differences are not significant, there is an indication of improved stand associated with this better control of onion smut, but yields do not reflect this.

Discussion

The onion maggot infestation in these experiments was extremely heavy and thus provided an excellent opportunity to compare the effectiveness of insecticides under test. Planting date was such that seedlings were attacked soon after emergence. Hatching of eggs was evident when the "come-up" count was taken on May 30, and on that date eggs could be readily be found around the seedlings. The 1969 season had a protracted period of cool wet weather and adult flies could be found in the field from late May through mid-July with little evidence of distinct population peaks. Plots receiving neither insecticide nor fungicide were almost completely wiped out by a combination of onion maggot and onion smut, and in those plots that received fungicide only, maggots had destroyed more than 75% of the original stand by July 16. These facts led us to conclude that treatments which provided good maggot control in these tests will work satisfactorily in grower use.

Under the conditions of these tests, a granular application in the seed furrow with VC-13, ethion, carbofuran, N 2596, chlorfenvinphos, dyfonate, Bayer 37289, Dasanit® or pp 211, provided good onion maggot control for the entire season. This agrees with evidence presented by Rawlins and Gonzalez (1966) and Rawlins and Lodge (1966) for Dasanit®, chlorfenvinphos, dyfonate, and carbofuran. Since this is the case, there seems no reason for additional spray treatments to the onion foliage directed toward control of the adult fly.

As pointed out in the introduction, onion growers in Ontario have depended on the organophosphate insecticides for onion maggot control since 1959. This presents a major concern in the event of resistance developing to this class of compounds. Of the insecticides included in our tests, the only compound outside the phosphate group that provided good onion maggot control is carbofuran which, as yet, has not been registered for use on onions in Canada.

Although control of onion smut was reasonably good with thiram or polyram, improved control was noted where higher rates of thiram were used. It is also concluded that some benefit is derived by a seed treatment with thiram in addition to the thiram included in the pesticide granule used as a furrow treatment.

There was no evidence of phytotoxicity from any of the treatments tested and yields in the order of 900 bushels per acre were obtained in plots where onion maggot and onion smut were adequately controlled.

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VERTICAL DISTRIBUTION OF RESIDUES OF ORGANOCHLORINE INSECTICIDES IN SOILS COLLECTED FROM SIX FARMS IN SOUTHWESTERN ONTARIO[1]

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Abstract

A study conducted on six farms indicated that in uncultivated soils residues of o,p'-DDT, p,p'-DDT, p,p'-DDE, p,p'-DDD, and dicofol were retained largely within the top 6 inches. In cultivated soils, residues of the organochlorine insecticides were fairly uniformly distributed to a depth of approximately 10 inches. In cultivated light mineral soil as much as 14% of the total residue was recovered from the 10- to 12-inch layer, indicating that some leaching will occur in the first few inches below the cultivated layer. However, in heavy mineral soil and muck soil, the total residue recovered at the 10- to 12-inch depth was generally $< 5\%$. Vertical distribution of the residues in soil is dependent on soil type, extent of cultivation, and the characteristics of the insecticide.

Introduction

Insecticide residues ultimately end up in the soil whether they are applied directly to the soil or to crops from which they are washed down into the soil by rainfall. Recent studies (Duffy and Wong, 1967; Harris *et al,* 1966; Saha *et al,*

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1968; Wilkinson *et al,* 1964) have shown that residues of some organochlorine insecticides are present in agricultural soils in Canada. Since most organochlorine insecticides are of limited solubility in water and are also strongly adsorbed and inactivated by soil (Harris, 1966), it is usually assumed that they will not move vertically through the soil to any great extent, and, therefore, will not contaminate underground water supplies. Earlier studies have indicated that most of the insecticide residue remains in the top 3 to 4 inches of soil (Burkhardt and Fairchild, 1967; Chisholm *et al,* 1950; Ginsburg and Reed, 1954; Hardie *et al,* 1964; Lauge and Carlson, 1955; Lichtenstein, 1958; Lichtenstein *et al,* 1962). However, some penetration to lower levels of the soil has been noted. Hardie *et al* (1964) found that dieldrin penetrated to a depth of 6 inches and tended to accumulate slightly at that level. Ginsburg and Reed (1954) found small amounts of DDT as deep as 12 inches in the soil. Lichtenstein (1958) and Lichtenstein *et al* (1962) found traces of DDT and the cyclodiene insecticides as deep as 9 inches in the soil, while more recently Nash and Woolson (1968) found that residues of the chlorinated hydrocarbon insecticides were distributed fairly uniformly throughout the upper 9 inches of the soil, with only small amounts present below that level. In conjunction with a study on the accumulation of organochlorine insecticide residues in soils we also examined the vertical distribution of these residues on six farms in southwestern Ontario. This report summarizes the results obtained.

Materials and Methods

Soil samples were collected from six farms in southwestern Ontario which had a history of extensive use of the organochlorine insecticides. The soil types comprised sandy loam (Farms 1-3), clay loam (Farm 4), and muck (Farms 5-6). At Farm 1, an orchard, samples were taken beneath and between the trees. The sampling procedure was as follows: an area of approximately 5 acres was selected in a field and 5 subareas were sampled within the 5-acre site. The samples were taken in 2-inch increments to a depth of 12 inches. One sample was taken from each subarea. The 5 corresponding strata samples were pooled, placed in plastic bags, and sealed.

Insecticide residues were extracted from the soil within 48 hours of sampling. Prior to extraction the soil sample was brought up to approximately 50% of field moisture capacity, if necessary. The extraction solvent was a 1:1 acetone:petroleum ether. The procedure used was to add the acetone fraction first, swirl it with the soil sample, and then add the petroleum ether fraction. On addition of the solvent to the sample, the container was placed on an end-over-end tumbler and rotated for one hour. The petroleum ether extract was freed of acetone by washing with distilled water, dried, and stored in a freezer until required for analysis.

Prior to analysis, preliminary separation and cleanup of the extract was accomplished by liquid-solid fractionation using activated florisil as the adsorbent. This procedure has been described in detail elsewhere (Sans, 1967).

The samples were analyzed by gas-liquid chromatography using a Varian Aerograph Model 205-B dual column gas chromatograph equipped with ⅛-inch × 6-foot glass columns and electron capture detectors. Two column packings were utilized: DC200 (5% on Aeropak 30) which was used for identification and quantitation and QF-1 (8% on Aeropak 30) which was used when additional verification was required. In cases where identification was still in doubt chemical conversion techniques prior to GLC were also utilized. These procedures have been described in detail previously (Sans, 1967). The samples were analyzed for: aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide,γ-chlordane, o,p'-DDT, p,p'DDT, p,p'-DDE, p,p'-DDD ,and dicofol. The lowest limit of detection was 0.002 ppm.

Results and Discussion

The soil samples contained from 5 to 8 of the 11 possible residues. The data (Table 1) indicate that vertical distribution in soil is dependent on several factors, including soil type, cultivation, and the insecticide itself.

The influence of soil type and cultivation on the vertical distribution can be best demonstrated using p,p'-DDT as an example (Figure 1). On Farm 1a, the orchard, the sample was taken beneath the trees. This soil was never plowed or cultivated and the results clearly indicate that where downward movement of DDT is dependent on leaching, only limited movement occurs. Forty-six percent of the p,p'-DDT was present in the 0 to 2, 32.5% in the 2 to 4, and 16% in the 4 to 6 inch layers. Thus 94.5% of the total p,p'-DDT recovered was in the top 6 inches of the soil. Of the remaining 5.5% distributed throughout the next 6 inches, nearly all of it was present at the 6- to 8-inch depth. Less than 1% of the p,p'-DDT was found at the 10- to 12-inch depth. By contrast, on Farms 2 and 4, the soil was plowed annually to a depth of 6 to 8 inches. On Farm 2, the soil was a sandy loam similar to that on Farm 1. However, here, only 64% of the p,p'-DDT was found in the top 6 inches. Nearly 11% was recovered at the 10- to 12-inch level. Thus, while cultivation is a major factor in the distribution of insecticides through the soil, it would appear that some leaching of p,p'-DDT will occur for the first few inches below the plough depth, particularly with a light mineral soil. A similar distribution was apparent in the soil sample collected at Farm 5, the clay loam. In this case, 55.9% of the p,p'-DDT was present in the top 0- to 6-inch layer. The 10- to 12-inch layer contained 3.7% of the total amount recovered. Since both soils were plowed to the same depth, it would appear that in the heavy mineral soil, p,p-DDT does not leach into the lower layers of the soil quite so readily as it did in the sandy loam. The muck soil (Farm 6) was disked to a depth of 8 to 10 inches and, as can be seen in Figure 1, this has resulted in fairly even distribution of the insecticide to 10 inches. The 0- to 6-inch layer contained 57.7% of the total p,p'-DDT recovered, the 10- to 12-inch layer, 4.9%. The distribution of o,p'-DDT, p,p'-DDE, p,p'-DDD generally followed a similar pattern. The distribution of the residues in cultivated soils is similar to the results obtained by Nash and Woolson (1968).

In soils, DDT is slowly degraded to DDE and DDD. It appears that this degradation is the result of microbial activity. Under aerobic conditions, DDT is apparently converted to DDE; under anaerobic conditions, to DDD (Guenzi and Beard, 1967). In earlier studies we have noted that the concentration of DDE is usually considerably higher than DDD (Harris *et al,* 1968). This is to be expected since in most agricultural soils, aerobic conditions prevail. In this study an interesting reversal in pattern occurred on Farm 5. This farm is situated on reclaimed land, below the level of Lake Erie. It is dyked, and each year the land is flooded in the spring. The excess water is subsequently drained off, and pumped out. However, for certain periods of the year, anaerobic conditions will prevail. Under these conditions, the DDD levels in the soil are considerably higher than DDE (Table 1).

It is suggested above that vertical distribution of insecticide residues in soil will be dependent not only on soil type and cultivation but also on the insecticide itself. Aldrin is a moderately volatile insecticide, and it has been demonstrated that vaporization is a major pathway in the dissipation of aldrin residues from soil (Harris and Lichtenstein, 1961). By contrast, dieldrin is virtually non-volatile in soil (Harris and Lichtenstein, 1961). Endrin, while persistent in soil, has been shown to dissipate relatively quickly when applied to the soil surface (Mulla, 1960). Figure 2 shows a comparison of the vertical distribution of aldrin, dieldrin, and endrin in the muck soil on Farm 5. Because of its volatility, aldrin residues were lower in the 0- to 2-inch layer than in the

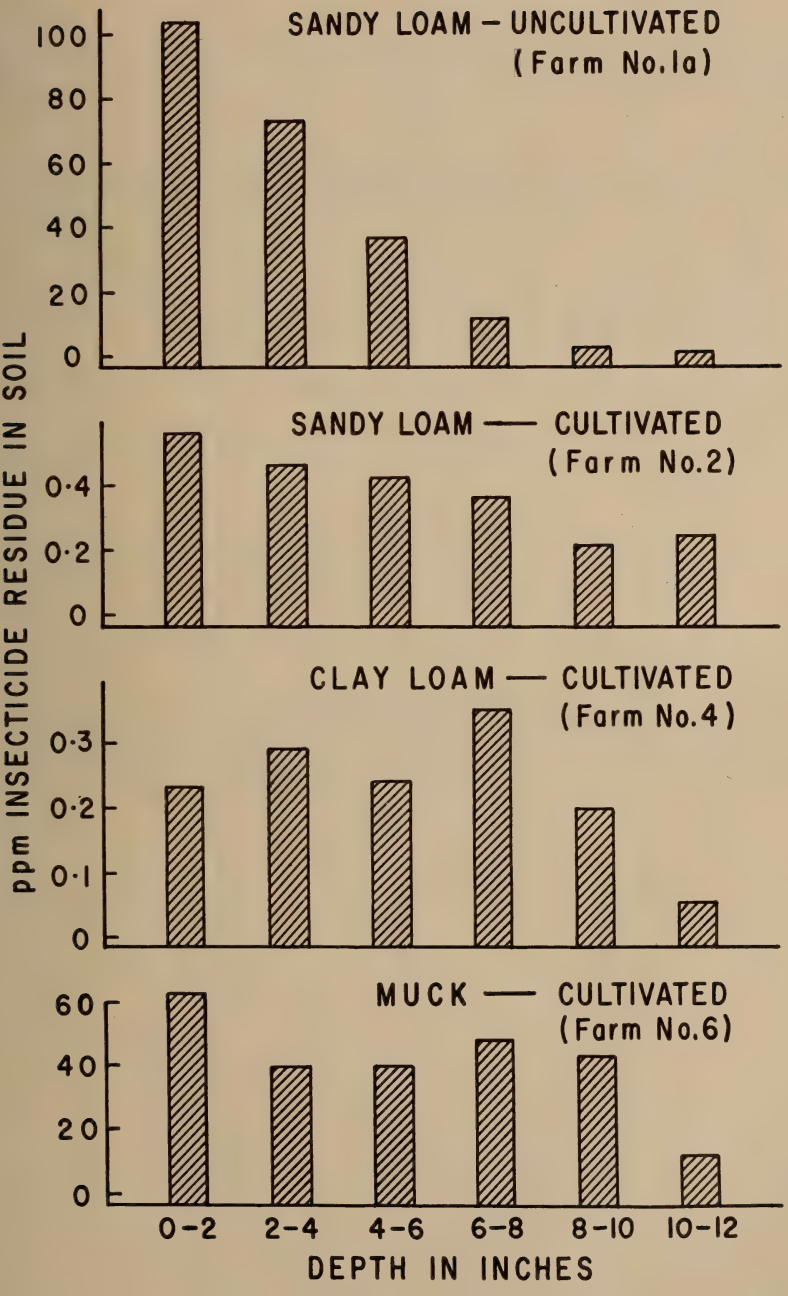

FIGURE 1. Comparison of the vertical distribution of p,p'-DDT in cultivated and uncultivated soils and on different soil types

TABLE I. Vertical distribution of organochlorine insecticide residues in top 12 inches of soil

Farm No.	Crop(s) Grown	Soil Type	Insecticide	Insecticide residues (ppm) at levels indicated (inches)					
				0-2	2-4	4-6	6-8	8-10	10-12
1a	Orchard	Sandy loam	o,p'-DDT	17.97	11.47	6.33	2.17	0.21	0.04
			p,p'-DDT	103.77	73.20	36.12	11.17	1.12	.16
(under trees)			p,p'-DDE	14.21	7.41	4.08	2.85	.35	.07
			p,p'-DDD	5.26	.87	.28	.11	.05	T[1]
			dicofol	6.16	2.59	1.35	.62	.12	.05
1b	Orchard	Sandy loam	o,p'-DDT	11.33	4.68	4.06	.66	.20	.09
			p,p'-DDT	44.90	32.13	29.02	3.56	.99	.53
(between trees)			p,p'-DDE	11.66	5.45	4.23	.68	.20	.22
			p,p'-DDD	1.63	.67	.16	.04	.03	.03
			dicofol	2.79	.95	.78	.16	.07	.07
2	Tobacco-potatoes	Sandy loam	aldrin	.19	.14	.03	.03	.10	T
			dieldrin	.47	.42	.32	.31	.33	.05
			endrin	.09	.07	.06	.06	.02	T
			o,p'-DDT	.10	.07	.10	.08	.05	.06
			p,p'-DDT	.56	.46	.42	.36	.21	.24
			p,p'-DDE	.15	.12	.11	.12	.06	.06
			p,p'DDD	.02	.02	.02	.02	.01	T

TABLE I (continued)

Farm No.	Crop(s) Grown	Soil Type	Insecticide	Insecticide residues (ppm) at levels indicated (inches)					
				0-2	2-4	4-6	6-8	8-10	10-12
3	Vegetables	Sandy loam	aldrin	.10	.12	.12	N/A[2]	.13	.02
			dieldrin	.56	.49	.49	N/A	.48	.07
			heptachlor	.03	.03	.03	N/A	.04	.01
			h. epoxide	.14	.14	.13	N/A	.15	.04
			y-chlordane	.11	.10	.09	N/A	.11	.03
			o,p'-DDT	.06	.06	.06	N/A	.06	.04
			p,p'-DDT	.27	.26	.26	N/A	.20	.16
			p,p'-DDE	.09	.09	.07	N/A	.08	.06
4	Crucifer	Clay loam	aldrin	.08	.22	.33	.35	.29	.03
			dieldrin	.81	1.16	.88	1.17	.75	.25
			o,p'-DDT	.04	.05	.05	.06	.03	.01
			p,p'-DDT	.23	.29	.24	.35	.20	.05
			p,p'-DDE	.09	.15	.10	.18	.08	.02
			p,p'-DDD	.03	.03	.02	T	T	T

TABLE I (continued)

Farm No.	Crop(s) Grown	Soil Type	Insecticide	Insecticide residues (ppm) at levels indicated (inches)					
				0-2	2-4	4-6	6-8	8-10	10-12
5	Vegetables	Muck	aldrin	1.84	3.09	2.63	2.86	.15	.04
			dieldrin	2.64	2.31	2.27	2.37	.64	.06
			endrin	5.11	7.14	10.52	10.14	1.42	T
			o,p'-DDT	1.18	1.88	2.34	2.50	2.87	.06
			p,p'-DDT	6.75	7.76	11.82	12.81	14.52	.24
			p,p'-DDE	.60	.97	.93	.99	1.06	.04
			p,p'-DDD	3.13	2.88	2.64	2.36	.30	.10
6	Vegetables	Muck	aldrin	.18	.15	.17	.36	.19	.14
			dieldrin	1.45	1.32	1.30	2.15	1.49	.47
			o,p'-DDT	12.31	8.63	9.28	12.37	8.71	2.33
			p,p'-DDT	61.64	39.28	39.80	48.02	42.98	12.06
			p,p'-DDE	3.43	2.66	3.33	4.05	2.79	.82
			p,p'-DDD	1.14	.87	.82	1.06	.65	.17

[1] T = trace = < 0.01 ppm

[2] N/A = not analyzed: sample accidentally destroyed

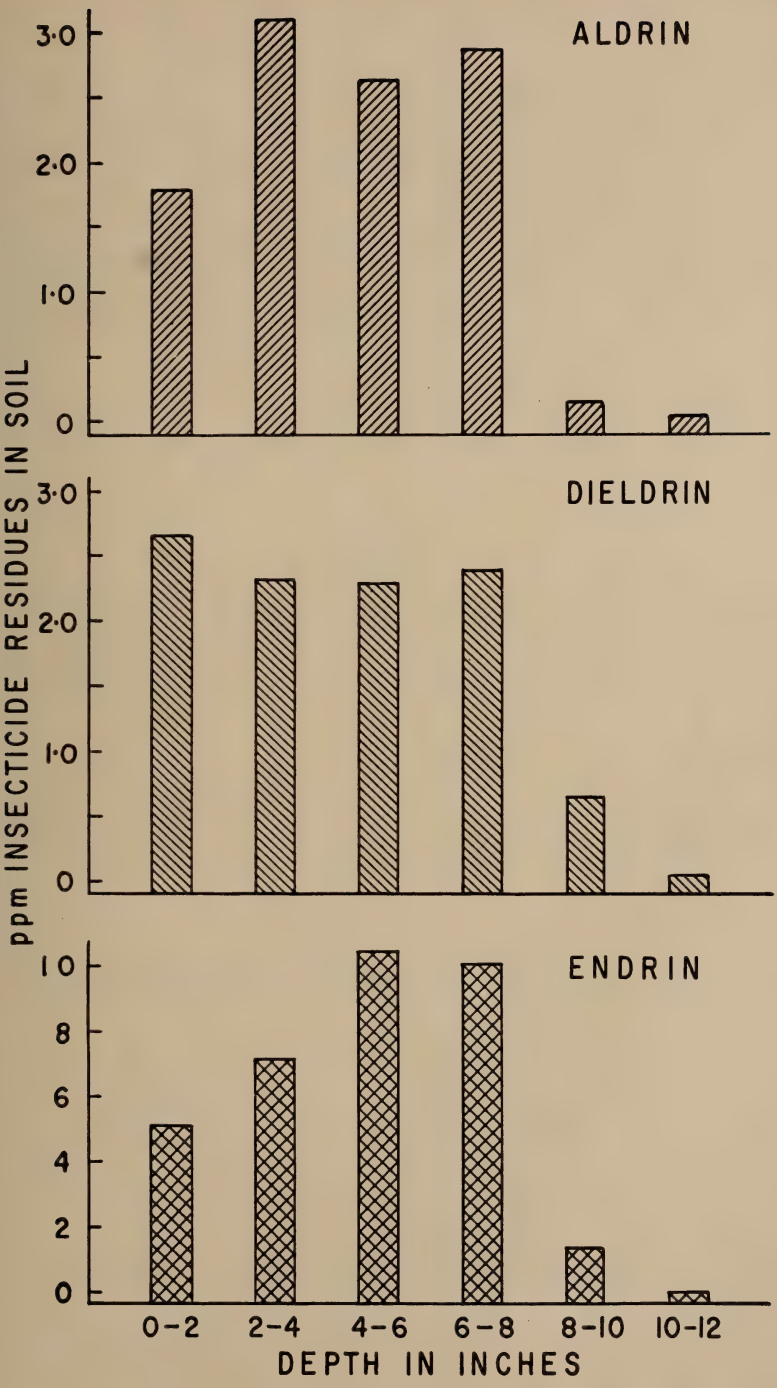

FIGURE 2. Comparison of the vertical distribution of residues of aldrin, dieldrin, and endrin in soil (Farm No. 5: Muck)

succeeding 2- to 4-, 4- to 6-, and 6- to 8-inch layers. Dieldrin residues were slightly higher in the 0- to 2-inch layer than in the succeeding three layers, while endrin residues were markedly lower in the 0- to 2- and 2- to 4-inch layers than in the 4- to 6- and 6- to 8-inch layers. Constant cultivation of soils is often suggested as a method of eliminating persistent organochlorine insecticide residues, by continually subjecting the residues to weathering. From the data in Figure 2 it would appear that this treatment would be helpful in elimination of aldrin residues from the soil, although some degradation to dieldrin would still occur; quite useful in the case of endrin residues in the soil, but of little value with dieldrin.

The results of this study indicate that in uncultivated soils, residues of the organochlorine insecticides are retained largely within the top 6 inches of the soil. In cultivated soils, the residues are fairly uniformly distributed to a depth of approximately 10 inches. With the exception of cultivated light mineral soil, the percentage of the total residue recovered at the 10- to 12-inch depth was generally <5%. In light mineral soils, as high as 14% of the total residue was recovered from the 10- to 12-inch layer, indicating that some leaching will take place in the first few inches below the plough depth. Vertical distribution of the residues in soil is dependent on soil type, extent of cultivation, and the characteristics of the insecticide.

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LABORATORY STUDIES ON THE CONTACT TOXICITY OF SOME INSECTICIDES TO HONEYBEES[1]

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Abstract

Tests on the contact toxicity of insecticides to honeybees, *Apis mellifera* L., indicated that many of the organophosphorus and carbamate insecticides now being developed or recommended in place of the organochlorine insecticides are more toxic. Using dieldrin as a standard, 12 of the 28 materials tested were more toxic as contact poisons.

Introduction

In most cases insecticides are, unfortunately, broad spectrum poisons. Consequently, they will be toxic not only to the pest species of insects which the entomologist wishes to control, but also to the beneficial species. Of major concern is the toxicity of insecticides to honeybees, *Apis mellifera* L., which are of major importance to agriculture. Because of severe restrictions on the use of the organochlorine insecticides, many less familiar compounds are being recommended for use, often without a thorough knowledge of the side effects which may occur. At our laboratory, new insecticides for both soil and vegetable insect control are being screened routinely. In 1969 we established beehives at our experimental farm to provide a supply of bees for inclusion in this screening program. This report summarizes results of tests completed on 29 insecticides.

Methods and Materials

The bees, a pure Italian strain, were maintained in five hives. Collections were made early in the morning when it was still cool and the insects were sluggish. Thus, it was not necessary to anaesthetize them. Only bees adjacent to the exits were collected. They were placed in wire mesh cages 2½ inches in diameter × 4 inches high, which were stoppered at one end with 1½ inch corks. Each cage contained approximately 50 bees. The collections were held at 80±1°F and 65±5% RH for 6 hours. No food was provided during this period. Prior to treatment the bees were anaesthetized lightly with ethyl ether. Recovery from the anaesthetic was rapid and little check mortality occurred.

The insecticides were analytical grade materials of a minimum of 95% purity. Solutions were made up in a 19:1 acetone:olive oil solvent mixture. Tests were conducted using a Potter spray tower. Each screening test comprised a control, utilizing the solvent mixture only, and insecticide concentrations of 0.001, 0.01, 0.1, and 1.0%. Two replicates, each with 10 insects, were treated at each concentration. Following treatment the bees were divided into two groups of five and placed in waxed paper cups covered with 9 cm glass petri dishes. Cotton wicks soaked in 50% honey solution were stapled to the edge of each container to provide a source of food. The observation containers were then placed in a constant temperature room maintained at 80±1°F, 65±5% RH, and 24-hour photoperiod. Mortality counts were made after 18 hours. All tests were repeated and the two sets of results averaged. Corrections for natural mortality were made using Abbott's formula (Abbott, 1925).

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[1]Contribution No. 439, Research Institute, Canada Department of Agriculture, London, Ontario
[2]The authors acknowledge the technical assistance of F. Gore.

TABLE I. Direct contact toxicity of some insecticides to honeybees

	Average corrected % mortality at indicated rates of application (% solution)			
	.001	.01	.1	1.0
methomyl	5	100	100	100
mevinphos	0	100	100	100
Dursban	0	100	100	100
carbofuran	0	100	100	100
parathion	0	100	100	100
Dupont 1642	15	90	100	100
naled	0	79	100	100
azinphosmethyl	0	78	100	100
dimethoate	0	78	100	100
Dasanit	0	72	100	100
carbaryl	0	68	100	100
BAY 77488	0	42	100	100
dieldrin	5	35	100	100
aldrin	0	11	100	100
BAY 37289	0	11	100	100
Landrin	0	0	100	100
Bux	0	0	100	100
heptachlor	0	0	100	100
diazinon	0	0	100	100
malathion	0	0	100	100
Imidan	0	0	100	100
Gardona	0	0	100	100
endrin	0	0	50	100
chlordane	0	0	17	100
chlorfenvinphos	0	0	17	100
DDT	5	10	15	100
endosulfan	0	0	0	100
Stauffer N-2596	0	0	0	100
methoxychlor	0	0	0	83

Results and Discussion

The results of the tests, listing the materials in descending order of toxicity are shown in Table 1. It is apparent that many of the insecticides now being developed or recommended in place of the organochlorine insecticides are far more toxic to bees as contact poisons. It is well known that carbaryl is more toxic to bees than the organochlorine insecticides and some of the other carbamate insecticides, e.g. methomyl, Furadan, and Dupont 1642 are even more toxic than carbaryl. In addition, a number of organophosphorus insecticides were also highly toxic. Using dieldrin as a standard of comparison, 12 of the 28 materials were more toxic. The order of toxicity for some of the materials compares favorably with results recently published by Stevenson (1968).

Under practical conditions the toxicity of the insecticides to bees will be dependent not only on their initial contact toxicity but also their persistence on the plants. Many of the newer insecticides persist for only a short period of time. However, others are moderately residual and could constitute a problem. In addition large differences in contact and oral toxicity can occur, and materials which appear to be "safe" as contact poisons may be highly toxic as stomach poisons. It is apparent that, in the future much greater care must be taken to insure that materials recommended for use as replacements for the organochlorine insecticides do not result in even more deleterious side effects.

Chemical Names of Experimental Materials without Approved Common Names

BAY 37289 - O-ethyl O-2,4,5-trichlorophenyl ethylphosphonothioate

BAY 77488 - Phenylglyoxylonitrile oxime O,O-diethyl phosphorothioate

BUX - m-(1-ethylpropyl) phenyl methylcarbamate mixture (1-4) with m-(1-methylbutyl) phenyl methylcarbamate

Dasanit - O,O-diethyl O-[p-(methylsulfinyl)phenyl] phosphorothioate

Dupont 1642 - methyl N-(carbamoyloxy) thioacetimidate

Dursban - O,O-diethyl O-3,5,6-trichloro-2-pyridyl phosphorothioate

Gardona - 2-chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate

Imidan - O,O-dimethyl S-phthalimidomethyl phosphorodithioate

Landrin - 3,4,5-trimethylphenyl methylcarbamate, 75%; 2,3,5-trimethylphenyl methylcarbamate, 18%

Stauffer N-2596 - S-(p-chlorophenyl) O-ethylphosphonodithioate

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SPERMATOZOA IN UNEMERGED FEMALE MOUNTAIN PINE BEETLES, *DENDROCTONUS PONDEROSAE* HOPKINS

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Abstract

Less than 2% of the female mountain pine beetles found grouped under the bark of ponderosa pine contained spermatozoa just prior to emergence. Within three days after emergence into standard collection jars, 15% of these same populations contained sperm. Mating in the jars is suspected.

Introduction

In recent years much effort has been devoted to studies of bark beetle attraction. It has been determined that unmated female beetles of the genus *Dendroctonus* produce an attractant (Vité and Gara, 1962), and that production of the attractant, and aggregating pheromone, ceases soon after mating (Jantz and Rudinsky, 1966). Since mating has long been known to occur under the bark soon after females attack new trees, it was assumed that emerging brood females would be virgins, with only a few parent adults contaminating new brood collections.

In a recent study (McCambridge, 1969) approximately 15% of female mountain pine beetles, *Dendroctonus ponderosae* Hopkins, examined from daily collections of emerging brood, contained spermatozoa. This was at great variance with Reid (1958) who found that less than 1% of freshly emerged females had mated prior to emergence. Further investigation was required to determine the earliest period in the beetle's life cycle when mating could occur. Such information would be of value not only for producing high-quality frass for attraction identification and synthesis, but for tests of beetle response to attractant substances.

Procedure

Mating by mountain pine beetles requires physical contact. Such contact could take place during the final month of beetle development after adults have enlarged the pupal chambers in which they formed to the extent of coalescence. At this time loosely formed groups of 20 or more beetles can often be found where there is no obstacle to the mating act.

Five collections of 100 females each were taken between July 23 and August 20, 1969. Throughout this period the beetles were found in groups, at first more or less in a row, chewing outward to enlarge the congregating chamber; later in loosely arranged groups. Beetles were collected regardless of sex and placed in jars which were held on ice until females could be identified and examined for sperm — a period of about 18 to 24 hours. Mating between the time of collection and physiological inactivation due to cold is unlikely. Additional beetles were also allowed to emerge naturally into collection jars. After at least three days, 100 ♀ ♀ were separated from ♂ ♂ and examined for sperm.

The techniques used in collecting and examining females were as follows. Infested trees were felled and small patches of bark carefully removed along the

top of the bole. This prevented undue disturbance of the beetles, and made it possible to collect them in groups. Beetles were sexed under 30 magnifications by means of tergite configurations illustrated by Hopkins (1909). Each female was then grasped venter upward and the sides of the abdomen firmly squeezed so that the vagina, accessory glands, spermatheca, and spermathecal pump were extruded as illustrated by McCambridge (1969). This was done under 40 magnifications. The chitinized pump and attached spermatheca were removed with fine tweezers, placed in physiological saline on a slide, covered, and examined under dark-field illumination of 240×.

Results and Conclusions

Spermatozoa were found in less than 2% of female mountain pine beetles grouped under the bark of ponderosa pine just prior to and during the early stages of beetle emergence (Table I). Despite the caution taken to prevent sample contamination by parent adults, a few may be included in the total of nine females found containing sperm.

TABLE I. Incidence of spermatozoa in female mountain pine beetles found in groups under ponderosa pine bark, 1969

Date of Collection	Group Condition	Sample Size ♀♀	♀♀ Containing Spermatozoa
July 23	Feeding outward in a row	100	1
July 29	Loose group randomly arranged	100	6
Aug. 7	Same as above. Some able to fly	100	1
Aug. 15	Same as above. Some able to fly	100	0
Aug. 20	Same as above. Some able to fly	100	1
	Total	500	9 = (1.8%)

A sample of 100 recently emerged females taken from the same population examined above (those taken from collection jars) contained 18 with spermatozoa.

From these data and our previous work cited we conclude:

1. Despite the fact that close proximity would allow mountain pine beetles to mate prior to emergence, they seldom do. Large samples of females taken from beetles grouped under the bark just prior to emergence were virtually all virgins. However, to be absolutely sure females are without sperm, callow adults of about Munsell color code 10YR2/2 must be collected from pupal chambers.

2. Approximately 15% of females examined throughout the emergence period contained sperm. It is highly unlikely that all of these females were parent adults. Since females under the bark just prior to emergence are virtually free of sperm, it appears that some beetles mate either immediately upon emerging, or, more likely, in the collecting jars.

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POLLEN ANALYSIS IN THE ECOLOGY OF BEES OF THE GENUS *BOMBUS* LATR. (HYMENOPTERA: APIDAE) IN SOUTHERN ONTARIO

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Abstract

An analysis is given of the pollen in the larval meconium from nests of *Bombus borealis* Kby., *B. fervidus* (Fabr.), and *B. rufocinctus* Cress. The range of plant species used as sources of pollen throughout the development of the colony was determined as was the extent to which each plant was utilized. Major differences were evident in plant utilization by these species of bees which had developed in the same area and at the same time.

Introduction

Darwin, in *On the Origin of Species,* recognized bumble bees as good pollinators of red clover (*Trifolium pratense* L.). His ideas were confirmed in the late 1800's, when the introduction of *Bombus* species to New Zealand resulted in the increased production of red clover seed from below economical levels to 300 to 400 pounds per acre (340 to 460 kilograms per hectare) (Montgomery, 1951; Gurr, 1957). Fye and Medler (1954), Hobbs (1957), and many others confirmed the role of *Bombus* species as pollinators of red clover in North America.

Although research has been done on the management of *Bombus* species for pollination (Holm, 1966), little information on quantitative methods of evaluating various *Bombus* species as pollinators of specific plants was available. Brittain and Newton (1933) examined the pollen on several species of bees, including some *Bombus* species collected in apple orchards, to determine what plants other than apple were visited by the bees for pollen. In Scotland, Brian (1951) examined me-

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conial pollen, as well as pollen on the bees, in the nests of three *Bombus* species. She obtained a list of the relative amounts of pollen from the plants which had been visited and pollinated by the bees from these nests. Faegri (1961) reported the results of the total pollen analysis of a nest of B. *lucorum* L. collected and described by Loken (1961) in Norway.

The work of Brian, Loken, and Faegri indicated that the examination of pollen in the meconium of the bee larvae would provide an estimate of the amounts of pollen collected from the different plant species by any species of bee. From these data, an evaluation could be made of the role of each species of bee in the pollination of plants.

Materials and Methods

A reference collection of pollen was made from identified, fresh plant material and from labelled material in the herbarium of the Botany Department, University of Guelph. All pollen was mounted in polyvinyl alcohol-lacto-phenol (Downs, 1943) with acid fuchsin stain. The reference collection and photographs of representative grains were used in the identification of pollen in the samples.

The study area was near Speedside about 10 miles (16 kilometers) north of Guelph, Ontario. Records were kept of the bloom-periods of plants on the site and of the major stands of plants within a one-mile radius of the site. In 1966, two nests of *B. fervidus* (Fabr.), two of *B. borealis* Kirby, and one of *B. rufocinctus* Cresson were located on the site and observed in domiciles until the colonies terminated. The nests were collected and the cocoons of each were divided into the consecutive brood-groups. Sampling was done within the brood-groups.

Small sections containing meconium were cut from the base of each cocoon sampled. These were soaked in chloroform and water on a spot-plate until the pollen grains dispersed. A thick film of the suspension was placed on each of two slides, mixed with one drop of mountant, covered, and air-dried for at least 12 hours. For each sample, 1,000 grains (500 per slide) were counted and identified to genus and species where possible.

Results and Discussion

A detailed study of the types of pollen in the sample was necessary to determine the range of variation which could occur in the size and in the collapse-pattern, compared with the normal expanded grains in each species. In some instances there were not sufficient characteristics of the pollen available to distinguish the species. For example, bees were seen foraging on *Penstemon digitalis* Nutt., *Trifolium hybridum* L., and some other Leguminosae, and some Rosaceae, but because of the similarity of the pollen, these species were grouped with *T. hybridum*. Similarly *Prunella vulgaris* L. and *Mentha arvensis* L. were grouped with *Nepeta Cataria* L. Pollen of the Pinaceae, the Gramineae, and the Compositae was not identified as to species. Although further identification might have been possible with more intensive study, the time involved was not warranted since *T. pratense* and *Echium vulgare* L., species with distinct pollen grains, made up the majority of the grains in the samples.

There appeared to be little fragmentation of the pollen exines in the meconial samples and the few fragments present usually could be identified. There was no evidence that any particular type of pollen grain was digested completely by the bee larvae.

The bloom-period records provided an estimation of the time during which pollen of any species in the area was available. The records were used mainly as a guide to the species of plant which might have provided pollen for the colonies studied. The periods of bloom of plants known to be visited by bumble bees in the study area are shown in Figure 1. Two distinct periods of bloom were evident for the plants of the leguminous hay crop. *E. vulgare* was abundant in the study area and provided bloom for 110 days. Since the distance a bee would fly to any particular pollen-source was not defined, more detailed records of the plants in a larger area might be necessary in studies of other florae.

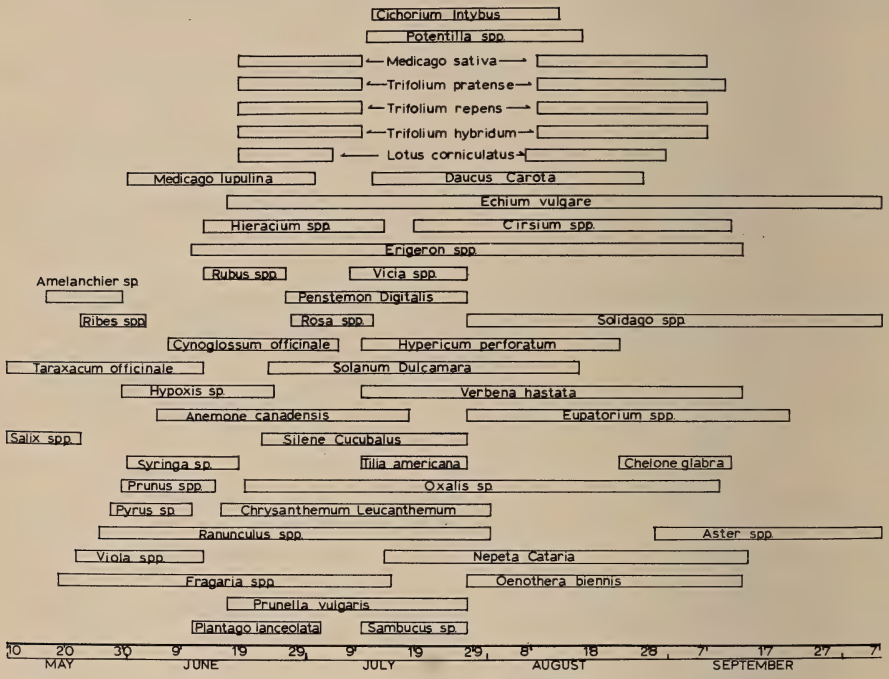

FIGURE 1. Periods of bloom of plants visited by bees

Whole nests, used as the units for pollen analysis, provided results which were linked with the biology of the colony. Removal of a significant amount of pollen as pollen-pellets from the foragers might be detrimental to the nutrition of the colony. The examination of meconial pollen permitted the bees to utilize the pollen and the colony to terminate normally. The meconium was concentrated as a hardened, dark brown mass in the basal third of each cocoon. When pieces of the cocoon were soaked in water, layers of cocoon-material were visible between the layers of meconium as was demonstrated by Faegri (1961). The suspensions of pollen exines in water and the films of pollen on each slide were relatively homogenous. The chloroform removed most of the wax and some of the oils from the samples but some lumps of pollen remained. As the pollen in these lumps could not be counted or identified accurately, it was omitted.

The sequence of the occurrence of pollen in the samples of each nest approximated the sequence in the bloom-records in most instances. Errors in distinguishing the cocoon-sequence could have been avoided by dating each group of cocoons accurately as the bees emerged. A system of date-markers which could not be removed by the bees could be used.

The percentage of cocoons sampled from each nest varied from 34 to 95. A comparison of the data from 94.87% of the cocoons of *B. fervidus* (#7) with the data from 33.33% of the same nest (Table I) indicated that the sampling could be reduced to include only one-third of the nest. With accurate dating of the brood groups, sampling might be reduced to one or two cocoons per group.

The counts and percentages of pollen from each plant species or group of plant species used throughout the season in each of the five nests sampled are given in Table II. The major pollen sources used by each of the three *Bombus* species are listed in Table III as percentages.

TABLE I. Pollen analysis of a nest of *Bombus fervidus* (No. 7) sampled according to cocoon group and based on sampling 94.87% of the nest, compared with 33.3% of the nest, Guelph, Ontario, 1966

Species	94.87% Sample		33.3% Sample	
	Total	%	Total	%
Trifolium pratense	14,225	38.45	5,391	41.47
Echium vulgare	14,618	39.51	4,995	38.42
T. repens	1,718	4.64	455	3.50
Vicia spp	221	.60	78	.60
T. hybridum and other species	4,370	11.81	1,471	11.32
Medicago sativa	346	.94	109	.84
Hypericum perforatum	316	.85	129	.99
Brassica kaber	578	1.56	157	1.21
Tilia americana	1	.01	1	.01
Gramineae	76	.21	29	.22
Compositae	26	.07	12	.09
Daucus Carota	2	.01	1	.01
Nepeta Cataria	18	.05	4	.03
Solanum Dulcamara	11	.03	2	.02
Rosaceae	167	.45	62	.48
Miscellaneous	278	.75	94	.72
Lotus corniculatus	3	.01	2	.02
Verbena sp.	5	.01	0	0
Fagopyrum sp.	4	.01	1	.01
Silene cucubalis	12	.03	5	.04
Pinaceae	4	.01	2	.02
Campanula sp.	1	.01		
Total	37,000	100.02	13,000	100.02

The *B. borealis* nests were established in late June about the time of the first bloom of red clover. When the nests were dug out of the ground in early August, a quantity of pure *T. pratense* pollen was found in one cocoon. More than 95% of the pollen identified from the two nests was from *T. pratense* and

TABLE II. Total counts and percentages of the pollen of each plant species or group of plant species used in the five *Bombus* nests from Speedside, Ontario, 1966

Plant Species	Species of *Bombus*									
	borealis No. 1		*borealis* No. 2		*fervidus* No. 7		*fervidus* No. 9		*rufocinctus* No. 2	
	Number	%	Number	%	Number	%	Number	%	Number	%
Trifolium pratense	24,392	54.20	19,356	62.44	14,225	38.45	49,175	52.31	3,040	6.08
Echium vulgare	18,641	41.42	9,916	31.99	14,618	39.51	22,008	23.41	8,223	16.45
T. repens	264	.59	102	.33	1,718	4.64	369	.39	465	.93
T. hybridum and other species	387	.86	321	1.04	4,716	12.73	15,697	16.70	30,848	61.70
Vicia spp.	190	.42	55	.18	221	.60	3	.01	2	.01
Hypericum perforatum	81	.18	183	.59	316	.85	77	.08	101	.20
Brassica kaber	45	.10	107	.35	578	1.56	24	.03	3	.01
Tilia americana	—	—	42	.14	1	.01	1	.01	27	.05
Gramineae	56	.12	42	.14	76	.21	32	.03	15	.03
Compositae	40	.09	91	.29	26	.07	459	.49	2,030	4.06
Daucus Carota	4	.01	—	—	2	.01	145	.15	8	.02
Nepeta Cataria	67	.15	31	.10	18	.05	78	.08	43	.08
Solanum Dulcamara	107	.24	58	.19	11	.03	686	.73	1,066	2.13
Rosaceae	330	.73	119	.38	172	.46	998	1.06	2,563	5.13
Miscellaneous	389	.86	571	1.84	279	.75	881	.94	407	.81
Lotus corniculatus	—	—	—	—	3	.01	3,361	3.58	1,128	2.26
Fagopyrum sp.	1	.01	1	.01	4	.01	—	—	23	.05
Silene cucubalis	—	—	—	—	12	.03	3	.01	6	.01
Pinaceae	6	.01	3	.01	4	.01	1	.01	3	.01
Oenothera biennis	—	—	2	.01	—	—	1	.01	—	—

TABLE III. The plants and the percentages of each used as the major pollen sources in the nests of three *Bombus* species from Speedside, Ontario, 1966

Plants	*B. borealis*	*B. fervidus*	*B. rufocinctus*
Trifolium pratense	57.56	48.40	6.08
Echium vulgare	37.58	27.95	16.45
T. repens		1.59	
T. hybridum and other species		15.58	61.70
Compositae			4.06
Solanum Dulcamara			2.13
Rosaceae			5.13
Lotus corniculatus		2.57	2.26
Total	95.14	96.09	98.81

E. vulgare, indicating a preference for these plants. A preference for *T. pratense* over *E. vulgare* was indicated both by the amounts of pollen and by the fact that, although *E. vulgare* was abundant on the site, the bees flew ¼ to ½ mile (0.8-1 kilometers) to obtain pollen of *T. pratense.*

Data from the single nest of *B. rufocinctus* were not considered representative of the species. They do however, differ from those of the other two species. The bees collected more pollen of the *T. hybridum* type than that of *T. pratense. E. vulgare* was important but was not used as much by *B. rufocinctus* as by the other species. Also, *B. rufocinctus* used more Compositae and Rosaceae pollen indicating that is was a more general forager.

Of the two nests of *B. fervidus, B. fervidus* No. 9 was considered a normal nest continuing from early July to September 20. Due to the death of the queen in an attempted supercedure, *B. fervidus* No. 7 terminated in early August prior to the second bloom of *T. pratense.* The data for *B. fervidus* from Table III indicate a preference for *E. vulgare* and the cultivated Leguminosae and in particular for *T. pratense.* The indication of a preference for *T. pratense* probably would have been greater had the data been collected from two normal nests (see data for *B. fervidus* No. 9 in Table II).

Definite statements of preference could not be made from the small amount of material that was used to demonstrate the value of this method of pollen analysis. Further studies of a significant number of nests of each species in various habitats would be required. The method, although in need of refining, did give an estimate of the range of plant species used as pollen sources and of the relative amounts of pollen in the nests of the three species of *Bombus.* It was considered useful in evaluating the pollinating abilities of various species of bees.

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INSECTS ASSOCIATED WITH FLOWERING WILD CARROT, *DAUCUS CAROTA* L., IN SOUTHERN ONTARIO

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Abstract

In 1968, 293 insects were collected from flowering heads of *Daucus carota* in southern Ontario. On five days in August, 150 were collected in Dunn Township, and on five days in August and September, 143 were collected in London. Orders represented in the collections were Orthoptera, Hemiptera, Coleoptera, Lepidoptera, Hymenoptera and Diptera.

Introduction

During August and September 1968, insects were collected from flowering heads of wild carrot, *Daucus carota* L., at two localities in southern Ontario. On August 10, 11, 17, 18, and 31, the collections were made in the extreme southwest corner of Dunn Township, Haldimand County, and on August 15, 21, and 28 and September 7 and 18, in a field on the south side of the Sarnia Road midway between Hyde Park Road and Hutton Road in London, Ontario. On each of these 10 days the sky was clear except for a few cumulus clouds, the temperature was between 75° and 80°F and only a light breeze was blowing, thus causing the flower heads to sway only slightly. The flowering heads were fully expanded, being from 2 to 4 inches in diameter. On each day of collection about one hour, beginning at 2 p.m., was spent in collecting the insects. Some insects were captured by being clapped between the lid and jar of a cyanide jar while others were swept from the flower heads with a net. Most of the insects were identified by the following taxonomists, all of whom, unless otherwise indicated, are members of the staff of the Entomology Research Institute, Department of

Agriculture, Ottawa: G. Ayre, Entomology Research Institute, Belleville, Ontario (Formicidae), D. Brown (Hemiptera), R. deRuette (Coleoptera), M. Ivanochko (Pompilidae, Sphecidae, Tiphiidae), W. R. M. Mason (Braconidae, Ichneumonidae), J. F. McAlpine (Sepsidae), H. E. Milliron (Colletidae, Halictidae, Tenthredinidae), O. Peck (Eulophidae, Pteromalidae), B. V. Peterson (Bibionidae, Scatopsidae), G. E. Shewell (Bombyliidae, Calliphoridae, Ceratopogonidae, Empididae, Ephydridae, Sarcophagidae), V. R. Vickery, Macdonald College, Quebec (Orthoptera), J. R. Vockeroth (Chironomidae, Muscidae, Syrphidae). Other insects were identified by the writer. All specimens are deposited in the collection of the Department of Zoology, University of Western Ontario, except some noted as "kept" in the collections of the institutions in which they were identified.

Account of Insects Collected

Altogether, 293 insects were collected from the plants, 150 of these in Dunn Township, and 143 in London. The collections from the two localities were thus closely similar in the number of insects collected. Most of the insects were feeders on nectar or pollen or were pollen collectors such as bees, and some (Anthocoridae, Reduviidae, Nabidae, Coccinellidae) were predators of other insects. In the following account "D" denotes insects collected in Dunn Township and "L" those collected in London.

Orthoptera
Gryllidae

Oecanthus quadripunctatus Beutenmuller — 14 (L) crickets, 4 kept: 2 nymphs, 3 females, August 21; 2 males, 2 females, August 28; 5 females, September 7. Vickery and Kevan (1967) record this species from Ontario. Its presence on wild carrot with the report of Walker (1963) that it is a herb-inhabiting species, and the presence of nymphs and adults is in accord with the report of Walker (1963) that nymphs occur up to near the end of August, and adults through August and September.

Tettigoniidae

Conocephalus brevipennis (Scudder) — 1 (L) long-horned grasshopper, September 7. This species is recorded from Ontario by Vickery and Kevan (1967) and has previously been collected at London in the Byron Bog by Judd (1960).

Hempitera
Miridae

Lygus lineolaris Slater and Davis — 7 bugs: 5 (D), August 18, 31; 2 (L), August 15, 21. This species is recorded as one of the most abundant of economic species, feeding on a great variety of plants (Kelton, 1955), and was previously recorded in London from the Byron Bog by Judd (1960).

Adelphocoris lineolatus (Goeze) — 1 (D) bug, August 31. It has been recorded from London in boneset in the Byron Bog by Judd (1969).

Adelphocoris rapidus (Say) — 1 (L) bug, September 7. It has been recorded previously from London in the Byron Bog by Judd (1960).

Anthocoridae

Orius insidiosus (Say) — 1 (D) bug, August 17. This is recorded by Herring (1966) as a common species in the eastern United States, being predacious on other insects in flower heads.

Orius tristicolor (White) — 2 bugs: 1 (D), August 10; 1 (L), August 15. Herring (1966) records that this species occurs in Ontario.

Reduviidae

Sinea diadema Fab. — 2 (L) bugs, August 15, September 7. Blatchley (1926) records this species as widely distributed in eastern North America, including Ontario, and reports that it is predaceous on other insects inhabiting weeds and grasses.

Tingidae

Corythuca marmorata Uhler — 2 (D) bugs, August 31. Blatchley (1926) records that this lace bug occurs commonly on plants in eastern North America, including Ontario.

Lygaeidae

Lygaeus kalmii Stal — 2 (L) bugs, August 28, September 19. Blatchley (1926) records this species from eastern North America where it occurs on plants, most commonly on milkweed.

Nabidae

Nabis ferus (L.) — 1 (L) bug, September 7. Blatchley (1926) records that this species occurs commonly on grasses and weeds where it is predacious on other insects. It was previously reported from London in the Byron Bog by Judd (1960).

Nabis sp. — 1 (L, nymph), August 15.

Coleoptera
Cantharidae

Chauliognathus pennsylvanicus DeG. — 15 beetles: 5 (D), August 10, 17, 18; 10 (L), August 15, 21, 28, September 7. Blatchley (1910) records this species as being common on plants, and Judd (1969) reported it previously in London on boneset in the Byron Bog.

Melyridae

Collops quadrimaculatus (Fab.) — 1 (D) beetle, August 10. Blatchley (1910) records that this beetle is common on grasses and foliage.

Phalacridae

Twenty-four beetles: 16 (D), August 10, 31; 8 (L), August 21, 28, September 7. Blatchley (1910) records that beetles of this family live principally on flowers, and Judd (1969) records them from boneset in the Byron Bog in London.

Coccinellidae

Coleomegilla maculata lengi Timb. — 3 beetles: 2 (D), August 10, 17; 1 (L), September 7.

Hippodamia tredecimpunctata tibialis (Say) — 1 (D) beetle, August 10.

Hippodamia glacialis (F.) — 1 (L), August 15.

Hippodamia convergens Guerin — 1 (L) beetle, August 21.

Hippodamia parenthesis (Say) — 1 (L) beetle, September 7.

Blatchley (1910) records that all these species of beetles occur on plants where they are predators of aphids and feed on pollen.

Chrysomelidae

Diabrotica undecimpunctata howardi Barber — 1 (D) beetle, August 17. This species is reported by Blatchley (1910) as occurring on many kinds of plants.

Diabrotica longicornis (Say) — 28 beetles: 3 (D), August 31; 25 (L), August 28, September 7. This beetle is reported by Blatchley (1910) as occurring commonly on many kinds of plants.

Lepidoptera
Euchromiidae

Cissipes fulvicollis Hbn. — 1 (L) moth, August 21. This species was found previously in London on boneset in the Byron Bog by Judd (1969).

Hymenoptera
Tenthredinidae

Tenthredo basilaris Say — 3 (D) sawflies, August 17, 18, 31. This species was collected previously on boneset in the Byron Bog by Judd (1969).

Braconidae

Agathis simillimus (Cresson) — 1 (D) wasp, August 31. This species is reported as occurring in Ontario as a parasite of various caterpillars (Muesebeck *et al,* 1951).

Apanteles crassicornis (Prov.) — 1 wasp (D, kept), August 31. This species is reported from Ontario by Muesebeck *et al* (1951) who record that wasps of this genus are parasitic on many species of caterpillars.

Ichneumonidae

Endasys subclavatus (Say) — 1 (D) wasp, August 11. Muesebeck *et al* (1951) record that this species is widely distributed in North America and is parasitic on sawflies.

Eulophidae

Hyssopus sp. — 3 (D) wasps, August 10. Muesebeck *et al* (1951) report that various species of this genus in North America are parasitic on tortricid caterpillars.

Pteromalidae

Zatropis (near *rosaecolis* Burks) 1 wasp (D, kept), August 17. Muesebeck *et al* (1951) report various species in this genus as parasitic on flies and beetles.

Merisus isosomatis (Ashmead) — 1 (L) wasp, September 7.Muesebeck *et al* (1951) record this species as being parasitic on flies.

Pompilidae

Dipogon brevis recalvus Townes — 1 wasp (D, kept), August 31. This species has been reported from Ontario by Krombein (1958).

Tiphiidae

Myzine quinquecincta (Fab.) — 1 wasp (L, kept), August 15. This species was previously reported from London on boneset in the Byron Bog by Judd (1969).

Formicidae

Myrmica americana Weber — 24 ants: 2 (D), August 18; 22 (L), August 15, 21, September 7.

Myrmica lobicornis fracticornis Emery — 1 ant (D, kept), August 10.
Crematogaster lineolata (Say) — 6 (D) ants, August 10, 17, 31.
Tapinoma sessile (Say) — 5 (D) ants, August 10, 17, 31.
Camponotus herculeanus (L.) — 1 (D) ant, August 10.
Lasius neoniger Emery — 8 (D) ants, August 10, 17, 31.
Formica pallide-fulva nitidiventris Emery — 4 (D) ants, August 10, 17.
Formica fusca L. — 27 ants: 14 (D), August 10, 17, 18, 31; 13 (L), August 15, 21, 28, September 7.

All the species of ants collected are reported as being common and widely distributed in North America by Muesebeck *et al* (1951).

Sphecidae

Sceliphron caementarium (Drury) — 2 wasps (D, kept), August 10, 11. This species is reported by Muesebeck *et al* (1951) as occurring in southern Ontario and throughout the United States.

Colletidae

Hylaeus ellipticus (Kirby) — 2 (D) bees, August 31. Muesebeck *et al* (1951) record this species as widely distributed in North America.

Hylaeus modestus Say — 3 bees: 2 (D), August 31; 1 (L), August 28. Muesebeck *et al* (1951) record this species from eastern North America.

Apidae

Bombus impatiens Cresson — 1 (D) bee, August 18. This species was previously recorded from boneset in the Byron Bog in London (Judd, 1969).

Apis mellifera L. — 3 (L) bees, August 21, 28. This species was the insect most commonly found on boneset in the Byron Bog by Judd (1969).

Diptera

Ceratopogonidae

One fly (D), August 10. Although flies of this family are blood-sucking insects, some are reported as visiting flowers (Stone *et al,* 1965).

Chironomidae

Chironomus sp. — 2 (D) midges, August 10.

Bibionidae

Dilophus stigmaterus Say — 1 fly (D, kept), August 31. Stone *et al* (1965) record this species as occurring throughout southern Canada.

Scatopsidae

Scatopse fuscipes Meigen — 2 (D) flies, August 10, 18. This species occurs throughout North America (Stone *et al,* 1965).

Bombyliidae

Villa sp. 1 (D) fly, August 10. Stone *et al* (1965) record various species in this genus as parasites of other insects.

Empididae

Hemerodromia sp. — 2 flies: 1 (D), August 10; 1 (L), August 15.

Syrphidae

Syrphus torvus Osten Sacken — 1 (L) fly, September 7.

Syrphus sp. — 2 (D) flies, August 11, 17.

Sphaerophoria contigua (Macq.) — 1 (L) fly, August 28.

Sphaerophoria robusta Curran — 3 (D) flies, August 17, 18.

Toxomerus marginatus (Say) — 1 (L) fly, August 21.

Paragus sp. — 1 fly (D, kept), August 17.

Syritta pipiens (L.) — 5 flies: 3 (D), August 11, 17, 31; 2 (L), August 15, September 7.

Eristalis arbustorum (L.) — 10 flies: 8 (D), August 11, 17, 18; 2 (L), August 15.

Eristalis tenax (L.) — 2 flies, August 15, September 18.

All the hover flies collected are of species recorded as being common and widely distributed in North America (Stone *et al,* 1965).

Sepsidae

Sepsis biflexuosa Strobl — 4 flies (D, 2 kept), August 10, 17. Stone *et al* (1965) record this species from southern Canada.

Ephydridae

Psilopa olga Cresson — 1 (D) fly, August 10. This species is recorded as occurring over much of North America (Stone *et al,* 1965).

Calliphoridae

Pollenia rudis (Fab.) — 17 cluster flies: 3 (D), August 10, 17; 14 (L), August 15, 21, 28, September 7.

Phaenicia sericata (Meigen) — 1 (D) fly, August 10.

Lucilia illustris (Meigen) — 11 flies: 10 (D), August 10, 17; 1 (L), August 15.

Bufolucilia silvarum (Meigen) — 4 flies (D, 3 kept), August 18, 31.

The cluster fly and the three species of blowflies collected occur commonly through southern Canada (Stone *et al,* 1965).

Sarcophagidae

Sarcophaga melanura Meigen — 2 flies (D, 1 kept), August 10, 31. Stone *et al* (1965) record this species from eastern North America.

Muscidae

Musca autumnalis DeGeer — 3 face flies: 2 (D), August 10, 17; 1 (L), September 7.

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THE LARVAL INSTARS OF *SIMULIUM RUGGLESI* NICHOLSON AND MICKEL (DIPTERA: SIMULIIDAE)

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Abstract

The black fly, *Simulium rugglesi* Nicholson and Mickel, (Diptera: Simuliidae), studied in a stream in Algonquin Park, Ontario, was found to pass through seven larval instars during its development. The external appearance of the larva in each of the seven instars is described.

Introduction

The black fly, *Simulium rugglesi* N. & M., has received some attention since it was found to be an important vector of *Leucocytozoon simondi* Mathis and Leger, a disease producing protozoan of ducks (Shewell, 1955; Fallis, Anderson and Bennett, 1956). The only published description of any larval stages of *S. rugglesi* has been that of the last instar by Wood *et al* (1962).

The number of larval instars in simuliids has received limited attention. Cameron (1922), using measurements of the posterior attachment organ, concluded that there were six instars for *S. simile* Malloch *(S. arcticum* Malloch). Puri (1925) followed the day-to-day development of *S. aureum* Fries and *S. erythrocephalum* de Geer and recognized six instars in each of these species. Also, Puri mentioned that Horvath recorded four instars; Tomosvary and Aigner-Abafi reported that there were five instars (species were not named); and that Edwards recognized six instars for *S. latipes* (Meigen). According to Terterjan (1957), *Odagmia kiritshenkoi* Rubz., and *Wilhelmia paraequina* Puri, each has six instars. Crosskey (1960) suggested that the existence of six larval instars was generally true for all simuliids. Harrod (1964) recorded six instars for *S. ornatum* var. *nitidifrons* Edwards. Davies, Peterson and Wood (1961) suggested that the number of larval instars varied from four to seven.

The intent of this paper is to describe briefly the larval instars of *S. rugglesi.*

Procedures

During the period May 15 to June 15, 1965, a section of the North Madawaska River between 200 and 500 meters downstream from the outlet of Lake Sasajewun, Algonquin Park, Ontario, was sampled extensively for black fly larvae. This part of the river was a known habitat of *S. rugglesi* (Pilfrey, 1963).

Determination of the widths of the cephalic apotome (frons clypeus) on the head of *S. rugglesi* larvae followed the method used by Harrod (1964), in which the maximum distance between the cephalic cleavage lines was measured under magnification of 100×. All measurements and descriptions were made from larvae which were preserved in 95% ethyl alcohol.

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Observations

The Number of Instars of *S. rugglesi*

Measurement of the width of the cephalic apotome of 580 larvae of *S. rugglesi* collected in 1965 was plotted (Figure 1A). The specimens in the grouping from 42.8 to 50.0 μ all had an egg-tooth or egg-burster, suggesting that they were first-instar larvae. The larvae in the grouping at 313 μ had well-developed pupal, respiratory filament histoblasts, indicative of final-instar larvae.

Seven definite groupings appeared, indicating that there were seven larval instars. Using Dyar's (1890) rule, as rephrased by Wigglesworth (1953), a plot of the logarithms of the mean width of the cephalic apotome for each instar resulted in a nearly straight line. Therefore Dyar's rule was considered to hold for *S. rugglesi* (Figure 1B).

A first-instar larva of *S. rugglesi,* in the process of shedding its head capsule, was collected. Its cephalic cleavage lines were indistinct, but the width of the entire head was only 90 μ. This would indicate the width of the cephalic apotome as about 75 μ in second-instar larvae.

Description of the Larval Instars of *S. rugglesi*

First-instar larva (Figure 2(A) (B)): Length 0.7 to 0.8 mm; width of cephalic apotome at widest point 43 to 50 μ. Body with irregular gray pigment; head capsule light brown; eye-spots red. Head fans present. Egg-burster or egg-tooth prominently located on cephalic apotome, the latter rounded posteriorly. Epicranial lobes meeting dorsally and posteriorly to cephalic apotome. Postgenal cleft very large, deep, and somewhat of a Gothic arch shape, extending anteriorly to labio-hypostomal fold. Ventral tubercles on abdomen nipple-like rather than conical.

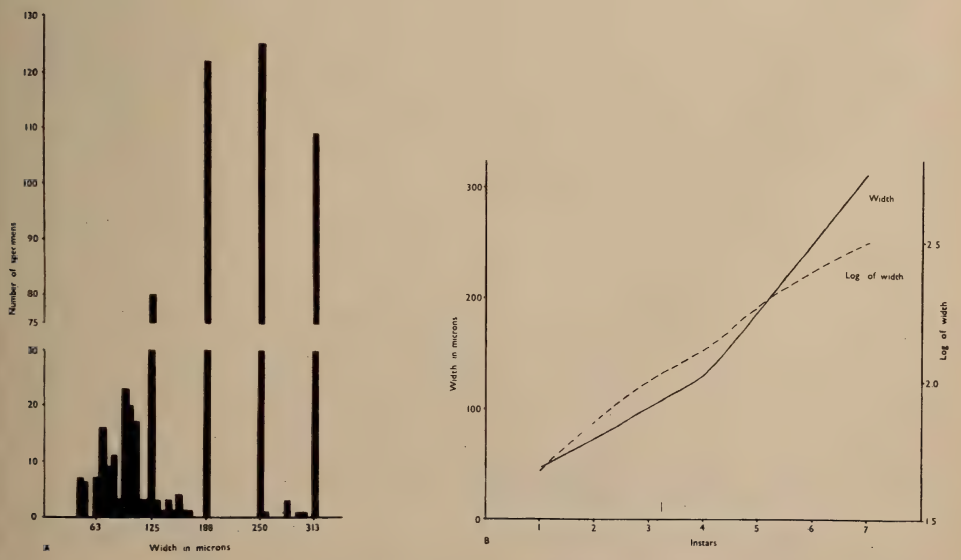

FIGURE 1.A Distribution of the widths of the cephalic apotome of 580 *S. rugglesi* larvae collected in the North Madawaska River, Algonquin Park, Ontario, in 1965

B Graph of the average widths of the head capsules in each larval instar of *S. rugglesi,* shown in actual micron measurements and also graphed as logarithms of the average widths

Second-instar larva (Figure 2(C) (D)): Length about 1mm; width of cephalic apotome at widest point 63 to 82 μ. Gray body pigment grouped in transverse bands; head capsule light brown; eye-spots red. Cephalic apotome color uniform light brown; posterio-lateral angles of cephalic cleavage lines quite definite and almost right-angled. Eye-spots located just forward of the angles of cephalic cleavage lines. Epicranial lobes just touching dorsally and posteriorly to cephalic apotome. Postgenal cleft deeper than in first instar; head capsule somewhat more elongate. Cleft still of Gothic arch shape, extending anteriorly to the labio-hypostomal fold. Ventral tubercles slightly more conical than in first-instar forms.
Third-instar larva (Figure 2(E) (F)): Length about 1.3 mm; width of cephalic apotome at its widest point 95 to 108 μ. Body either with a gray-green pigment in transverse bands or lacking pigment; head capsule light brown; eye-spots reddish black. Posterio-lateral angles of cephalic cleavage lines more rounded than in second instar and slightly obtuse. Epicranial lobes not quite meeting dorsally. Postgenal cleft similar in form and shape to that of the second-instar larva. Ventral tubercles definitely conical.
Fourth-instar larva (Figure 2(G) (H)): Length 1.5 to 1.7 mm; width of cephalic apotome at its widest point about 125 μ. Body with transverse bands of gray-green pigment; head capsule light brown; eye-spots reddish black. Post-occiput slightly darker than rest of head capsule. Posterior angles of cephalic cleavage lines rounded and definitely obtuse; epicranial lobes definitely not meeting dorsally. Postgenal cleft with slightly narrowed base; cleft extending to the labio-hypostomal fold. Shape of cleft in some specimens more of a rounded spear-head than arch form of previous instars. Ventral tubercles conical.

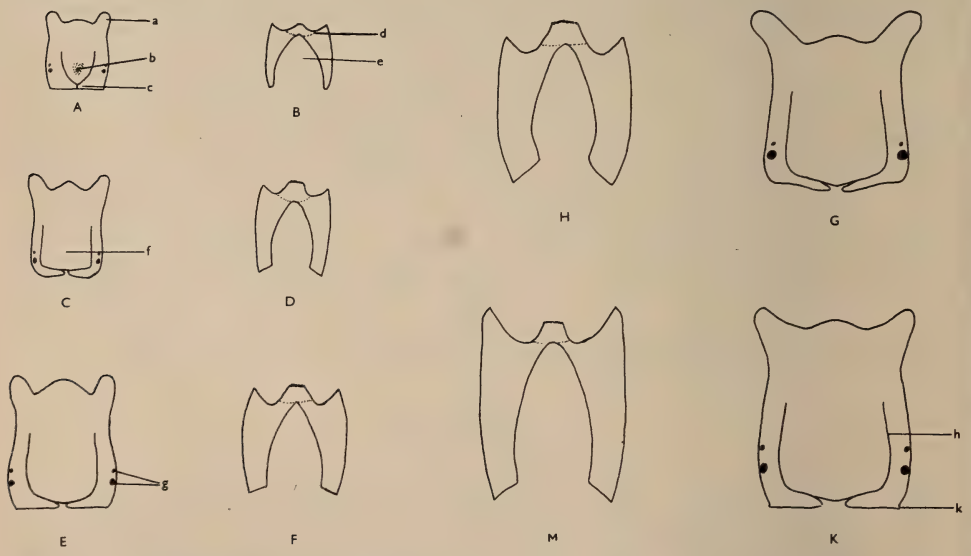

FIGURE 2. Head capsules of *S. rugglesi* larvae
A Dorsal view, first instar, ×140
B Ventral view, first instar, ×140
C Dorsal view, second instar, ×140
D Ventral view, second instar, ×140
E Dorsal view, third instar, ×140
F Ventral view, third instar, ×140
G Dorsal view, fourth instar, ×160
H Ventral view, fourth instar, ×160
K Dorsal view, fifth instar, ×115
M Ventral view, fifth instar, ×115

a - Head fan stalk
b - Egg-burster
c - Epicranial lobe
d - Labio-hypostomal fold
e - Postgenal cleft
f - Cephalic apotome
g - Eye-spots
h - Cephalic cleavage lines
k - Post-occiput

Fifth-instar larva (Figure 2(K) (M), Figure 3(E)): Length 2 to 2.5 mm; width of cephalic apotome at its widest point about 188 μ. Body with transverse bands of gray-green pigment; head capsule light brown; eye-spots very dark reddish brown. Post-occiput dark brown; cephalic apotome with several patches of brown, slightly darker than the general head color. Posterior angles of the cephalic cleavage lines slightly rounded and almost right angles; sutures converging anteriorly. Epicranial lobes with a dorsal gap. Postgenal cleft terminating anteriorly, in arch or spearhead shape, to the labio-hypostomal fold. Thorax with white imaginal and pupal buds; prothoracic leg-buds present at base of anterior sucker; dorsal to these were pupal respiratory histoblasts. Mesothoracic leg-buds ventrolaterally on meso-thorax; dorsal to each of these, the slightly larger wing-buds. Posterior to meso-thoracic leg-buds, were the similarly sized metathoracic leg-buds. Dorsal to these were the slightly larger haltere-buds.

Sixth-instar larva (Figure 3(A) (B) (F)): Length 3 to 3.5 mm; width of cephalic apotome at its widest point about 250 μ. Body pigmented in transverse bands of gray-green or light to dark reddish brown. Head capsule dark brown with faint, slightly darker brown markings on cephalic apotome. Eye-spots black.

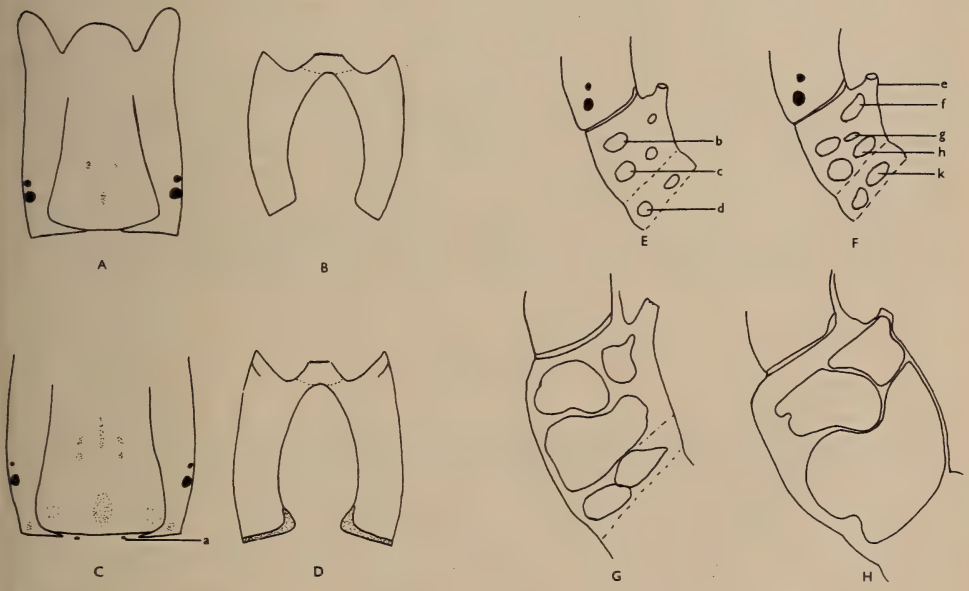

FIGURE 3. Head capsules and lateral views of *S. rugglesi* larvae
A Dorsal view of head capsule, sixth instar, ×88
B Ventral view of head capsule, sixth instar, ×110
C Dorsal view of head capsule, seventh instar, ×83
D Ventral view of head capsule, seventh instar, ×88
E Lateral view of thorax of fifth-instar larva, ×45
F Lateral view of thorax of sixth-instar larva, ×34
G Lateral view of thorax of young seventh-instar larva, ×50
H Lateral view of thorax of mature seventh-instar larva, ×44

a - Cervical sclerite
b - Respiratory filament bud
c - Wing bud
d - Haltere bud
e - Anterior sucker
f - Lateral plate
g - Prothoracic leg-bud
h - Mesothoracic leg-bud
k - Metathoracic leg-bud

Posterio-lateral angles of cephalic cleavage lines sharply rounded and right-angled, converging anteriorly. Epicranial lobes separated dorsally by a distance of about one-third the width of the cephalic apotome. Postgenal cleft more bluntly spear-shaped in some specimens than in others, cleft closing anterior to the labio-hypo-stomal fold. Posterior tentorial pits definitely marked. On thorax, imaginal and pupal buds slightly larger than in previous instar, still white in color. Pupal respiratory histoblasts enlarged ventrally; prothoracic leg-buds enlarged towards tip of anterior sucker.

Seventh-instar larva (Figure 3 (C) (D) (G) (H)): Length 3.5 to 5 mm; width of cephalic apotome at its widest point about 313 μ. Body pigment in transverse bands of gray-green, gray or light to dark reddish brown. Head capsule dark brown; head-spots and other markings as described by Wood *et al* (1962); eye-spots black. Posterio-lateral angles of cephalic cleavage lines rounded and slightly acute. Epicranial lobes separated dorsally by a distance 0.6$\times$ that of the width of the cephalic apotome. Cervical sclerites prominent. Postgenal cleft still long, deep and arch-like or spearhead shaped in form, with rounded tip in some specimens only reaching the labio-hypostomal fold. Early seventh-instar larvae with pupal respiratory histoblasts of a white or creamy color; individual filaments barely distinguishable. Wing-buds and mesothoracic leg-buds on each side appearing to have united. Haltere-buds and metathoracic leg-buds touching meso-laterally. Mature seventh-instar larvae with individual pupal respiratory filaments easily visible, the whole organ being grayish-black in color. Imaginal buds still white or creamy white. Prothoracic leg-bud larger and filling space between pupal histoblasts and tip of anterior sucker. Wing-buds, haltere-buds, mesothoracic leg-buds, and metathoracic leg-buds on each side appearing to have joined and obscuring divisions amongst themselves; meso- and meta-thorax appearing completely filled with imaginal bud. Wings faintly distinguishable in wing-buds. Ventral tubercles less prominent in some specimens than in others.

Discussion

Harrod (1964) stated that *S. ornatum* var. *nitidifrons* did not follow Dyar's rule. Plotting of the logarithms of the mean widths of the cephalic apotomes, given in her 1964 paper, substantiated this. Similar logarithmic plotting of the distances between eye-spots, as given in Terterjan (1957) for *Wilhelmia paraequina,* gave a curved line instead of a straight line. It must be noted, however, that these studies were on reared or laboratory maintained populations of insects.

As can be seen from Figure 1A, the numbers of early-instar larvae found were small. It was first thought that only six instars were present and that the larvae now grouped as second and third instars were all actually second instar. However, it was obvious that the change in width of the cephalic apotome from 46 to approximately 100 μ and the change in body length from 0.6 mm to 1.3 mm (if the larvae considered now as third instar were really only large second-instar larvae) was far too great to be accomplished in a single molt. The first-instar larva found in the act of shedding its head capsule confirmed the specification for a second-instar larva as given above.

Dyar's (1890) rule suggested that there was a geometric increase in the ratio of the width of the head capsule of successive instars of larval Lepidoptera. *S. rugglesi* seemed to follow this rule rather well; plotting of the logarithm of the average width of the cephalic apotome at each stadium resulted in a nearly straight line (Figure 1B). Dyar's rule therefore substantiated the observation of seven larval stages for *S. rugglesi.*

Acknowledgment

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TWO NEW PARASITES OF THE TARNISHED PLANT BUG IN ONTARIO: *LEIOPHRON PSEUDOPALLIPES* AND *EUPHORIANA LYGIVORA* (HYMENOPTERA: BRACONIDAE, EUPHORINAE)

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Abstract

Leiophron pseudopallipes new species and *Euphoriana lygivora* new species, parasites of *Lygus lineolaris* (P. de B.) in Ontario, are described. The former parasite species is associated with *L. lineolaris* breeding on wild composites and other weeds; the latter with *L. lineolaris* on *Solidago canadensis* L. Populations of *pseudopallipes* are separated from *Leiophron pallipes* Curtis by differences in field biology and characters of the antenna, male genitalia, and wing venation.

Introduction

Among the complex of insects parasitic on *Lygus lineolaris* (P. de B.) in North America is the Holarctic braconid *Leiophron pallipes* Curtis (Clancy and Pierce, 1966). The life cycle of *pallipes* in Ontario differs from that known for other species of *Leiophron* by the occurrence of two discrete populations of immature stages and adults (Loan, 1965). These temporally-separated populations are composed of separate species, and those braconids constituting the later population (August and September, chiefly) are here described as *pseudopallipes.* It is, apparently, the species introduced into California from New Jersey for *Lygus* control (Clancy and Pierce, 1966; M. H. Brunson, *in litt.*), and whose host plant preference was investigated by Streams *et al* (1968) in Connecticut. The earlier population, flying in eastern Canada chiefly in May and June is *pallipes* Curtis and differs from *pseudopallipes* by phenological and morphological characters.

Lygus lineolaris is also parasitized by *Euphoriana uniformis* Gahan in the northeastern United States and the discovery of this braconid in Ontario was expected. However, a new species *E. lygivora* was associated with this mirid from rearings in the Belleville, Ontario, district.

L. pallipes is the commonest *Leiophron* species in the Canadian National Collection and in the United States National Museum. It is widely distributed and easily collected from grasses and forage legumes in early summer. Various hosts are recorded for *pallipes* in Europe (Brindley, 1939) and North America (Arrand and McMahon in Craig, 1963; Loan, 1965). However, Arrand and McMahon's records of *Chlamydatus* sp. and *Plagiognathus medicagus* Arrand in Saskatchewan are erroneous as the reared parasite is not *pallipes* (unpublished data).

The synonyms of *pallipes in* North America are *Microctonus punctatus* Provancher and *Euphorus mellipes* Cresson and, in Europe, *Microctonus barbiger* Wesmael (Muesbeck, 1936). The types of *punctatus* and *mellipes* were examined to determine if either is the type of the sibling population of *pallipes.* That of *mellipes* is badly damaged (gaster missing, antenna broken); the head of the lectotype of *punctatus* is missing. The evidence from either type is obviously inadequate and in any case a large type series is needed to assess the variation. These do not exist, and it seems best to retain the present Nearctic synonymy of *pallipes,* and provide a new name for the sibling population. The description

of *barbiger* refers to specimens with antennal segments of up to 30. This number, however, is out of the range of *pallipes* (maximum 27) and suggests that *barbiger* may include several species. This problem, and the possible Palearctic occurrence of *pseudopallipes* require investigation.

Types and paratypes of the new species will be deposited in the Canadian National Collection (CNC) and other paratypes of *pseudopallipes* only, in the collections of the United States National Museum and of the University of Connecticut.

Leiophron pseudopallipes, New Species

Holotype — Female (CNC11587) Fuller, Ontario, Canada, latitude 44° 24'N, longitude 77° 25'W, reared August 3, 1967, from nymphs of *Lygus lineolaris* collected September 4, 1966, feeding on *Solidago canadensis* L., C. C. Loan.

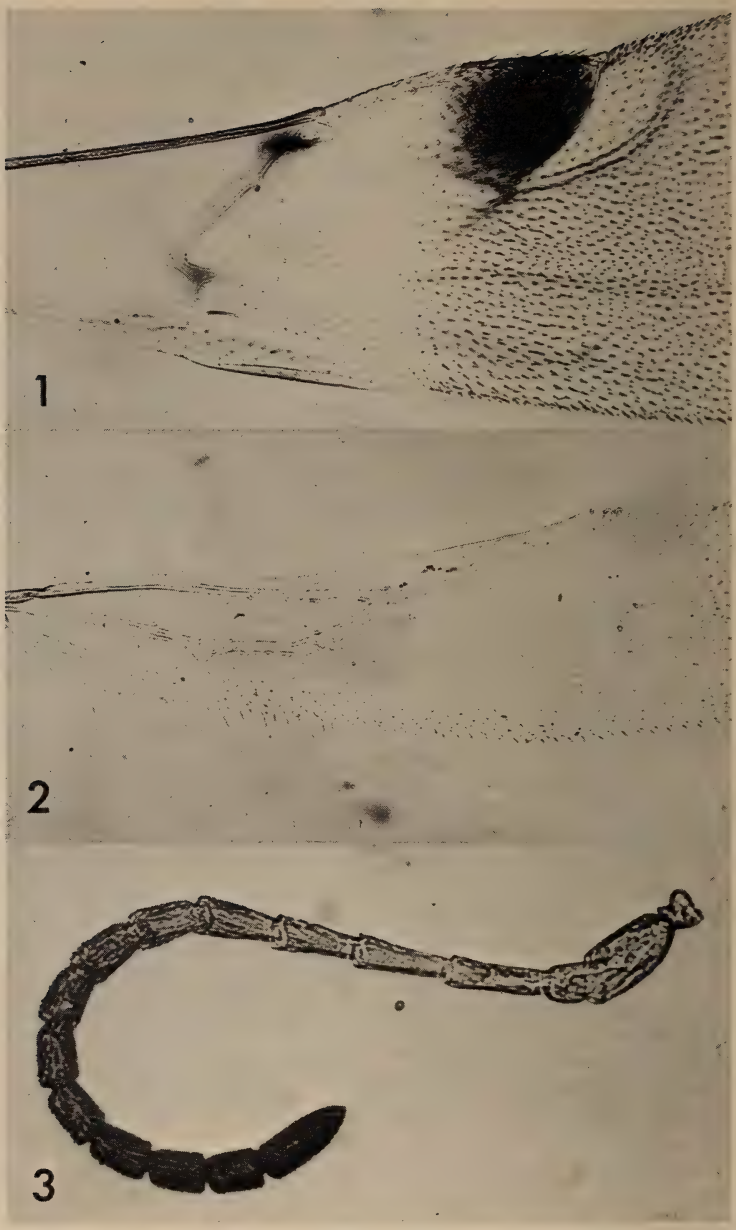
Length 3.0 mm. Dark reddish brown: scape, blade of mandible except apex light yellow; clypeus, pedicel, basal segments 1-3 of flagellum, fore and midlegs light brownish yellow, not as pale as scape; segments 4-19 of flagellum dusky; tibia of hind legs light dusky; gaster behind tergite 1 light reddish brown.

Head rectangular, wider than thorax (29:22), 2.0 times as wide as deep from eye to basal articulation of mandible; lower face from antennal sockets to base of clypeus slightly longer than wide, shagreened between eyes, dull, covered with appressed, white hair in side view; malar space not as long as basal width of mandible (2:3), 2.0 times as long as pedicel and subequally as long as segment 3 of flagellum; antenna 21-segmented, flagellum 3.4 times as long as width of head at vertex, 2.0 times as long as hind tibia; segment 1 of flagellum about as long as scape and pedicel together, longer than segment 2 (14:9) and 3 (14:8); apical segment more than 2.0 times as long as penultimate segment, not quite as wide; eye almost as wide as face between eyes (10:11), only slightly wider than temple (10:9), 1.6 times as long as wide; frons of upper face medially carinate, depressed near antennal sockets, completely punctulate, finely hairy; OOL not quite as long as POL; space from median to lateral ocellus 0.6 times as long as OOL; vertex shiny, weakly punctate; occipital carina complete.

Scutum of mesonotum covered with fine hair, indistinctly sculptured by shallow, oblong depressions; lateral lobes shiny, relatively smooth, mostly glabrous except thinly hairy next to scutum; foveae of prescutal sutures carinate, wide, rather deep; mesepisternum rugulose, partly smooth anterolaterally; fore wing 0.8 times as long as body excluding antenna; stigma 2.4 times as long as broad; first abscissa of radius short, almost punctiform, perpendicular: radial cell at wing margin slightly more that 0.3 times as long as stigma; nervellus and basal abscissa of basella subequal, not quite as long as apical abscissa; hind tibia 1.4 times as long as hind femur, almost as long as gaster behind tergite I(35:36); propodeum uniformly, closely rugulo-reticulate, slightly wider than long (7:6), posterior face somewhat flat, not excavated.

Gaster slightly more than 0.5 times as long as head, thorax and propodeum together; tergite 1 rugulo-striate with some medial reticulae, 1.5 times as long as wide at apex.

Allotype — Male, data as cited for female holotype except reared July 29, 1965. Similar facies as holotype. Antenna 24 segments, flagellum longer, robust basally diminishing in width apically; segment 1 of flagellum only slightly longer than 2 (6:5).



FIGURES 1 to 3. *Euphoriana lygivora*. 1. fore wing; 2. hind wing; 3. antenna (left side, paratype female).

Paratypes — 79 females, 93 males, with data listed below.

Locality records — The type series includes material chiefly from northeastern North America with one record from Ohio and one from Georgia. Material from the western provinces is excluded because of close resemblance between *pseudopallipes* and *pallipes,* because of lack of reared material, and because little or no field data are associated with specimens. Much of it is

probably *pallipes* judging by dates of capture which are chiefly in June and July. Regional variation was apparent, for example, the size of the phallus of British Columbia material is intermediate between eastern *pallipes* and *pseudopallipes,* and the median number of flagellar segments is like that of *pseudopallipes.* Rearings and host data are needed to determine the basis of the variation.

CANADA: **Quebec:** One female, Lac Brûlé, July 21, 1947, O. Peck; one female, Cascapédia, August 3, 1954, J. E. H. Martin; one male, Mistassini, August 3, 1956, J. R. McGillis. **Ontario:** one female, Strathroy, July 21, 1924, H. F. Hudson; one male, Ottawa, August 3, 1947, W. R. M. Mason; one female, Bells Corners, July 20, 1941, G. S. Walley; one male, Ottawa, July 25, 1951, J. E. H. Martin; one male, one female, Marmora, August 15, 1952, C. Boyle; one male, one female, Brighton, July 21, 1954, J. C. Martin. The following were swept, or reared from *Lygus lineolaris* collected at or near the type locality: two males, 13 females, September 2, 1962, swept from *Chenopodium alba* L.; 23 males, three females, August 3 to 6, 1963, swept from *Solidago canadensis;* two females, July 25 to 26, 1964, swept from roadside composites; three males, eight females reared July 29 to August 7, 1965; two males reared July 23 to 27, 1966; two males, three females reared August 4 to 8, 1967, C. C. Loan. UNITED STATES: *Connecticut:* two females, E. Hartford, August 20, 1947, Howard E. Evans; 44 males, 15 females, Storrs, July 9 to August 12, 1969, F. Streams. **Georgia:** one female, Hiawasee, August 19, 1957, L. A. Kelton. **New Jersey:** three females, Moorestown, July 26, 1963, swept in weedy field, F. Streams; two males, five females, 1963 (no other data); four males, six females Burl County, August, 1964. **New York:** two females, Ithaca, August 10, 1947; two females, Slaterville, August 25, 1951, C. Dasch. **Ohio:** one male, Steubenville, September 4, 1950, J. C. Martin; one female, August 17, 1951, C. Dasch.

Remarks

Specimens of *pseudopallipes* and of *pallipes* are so alike that, except for the maximum number of antennal segments, Muesebeck's (1936) diagnosis of *pallipes* covers the two species. Antennal characters, wing venation, and male genitalia are characters enabling separation of populations of the two species. No doubt there are others, though the ratios between various landmarks of the head, between the combined pedicel and scape and basal flagellar segments 1-3, between the malar space and flagellar segment 3 and between the length and apical width of tergite 1 of the gaster appeared similar. Characters counted, or measured (values in mm) with differences between means significant at the 5% level are as follows:

	pseudopallipes			*pallipes*		
	N	Mean	SE	N	Mean	SE
Parameres of						
phallus length	25	0.204	0.0020	25	0.183	0.0020
basal width	25	0.183	0.0034	25	0.162	0.0038
Stigma						
length	46	0.461	0.0043	49	0.499	0.0074
Nervellus						
length	27	0.120	0.0021	44	0.30	0.0026
Basella length of						
basal abscissa	29	0.133	0.0024	45	0.148	0.0023
apical abscissa	29	0.155	0.0029	44	0.167	0.0025
Flagellum						
length	31	2.26	0.0314	20	2.41	0.0441
	36	1.84	0.0258	28	2.05	0.0299
no. segments	25	22.00	0.0577	25	23.12	0.1779
	25	19.12	0.1224	25	21.12	0.1868

These data show that the parameres of the phallus of *pallipes* are neither as long nor as wide basally as the parameres of *pseudopallipes*. This difference is not related to body length as the difference between the means of the length of the first posterior tarsal segment was not significant. Each of the wing characters listed is longer in *pallipes*. However, neither the length of the radial cell, a good taxonomic character in the *Leiophron* group, nor the width of the stigma differed significantly. The antenna of *pallipes* is longer with 1 or 2 more segments than that of *pseudopallipes*. It should be noted that in this evaluation, the apical segment of the flagellum was considered to be 1 segment only, even if it was 2.0 times or more as long as the penultimate segment and showed a suggestion of segmentation. Frequency distributions of the number of flagellar segments of each species are as follows:

		No. of flagellar segments								
		17	18	19	20	21	22	23	24	25
♂	*pseudopallipes*					21	45	15	1	
	pallipes					1	10	39	43	10
♀	*pseudopallipes*	2	7	31	21	3	1			
	pallipes			6	25	49	19	2		

Biology

L. pseudopallipes was reared from two *Lygus* species in the Belleville district: *lineolaris,* breeding on weeds *(Chenopodium, Amaranthus)* and wild composites *(Solidago, Aster, Erigeron, Eupatorium)*; and *vanduzeei* Knight, a monophagous, univoltine mirid found on *Solidago*. The phenology and incidence of *pseudopallipes* parasitic in *lineolaris* breeding on *Chenopodium* has been reported (as *pallipes,* Loan, 1965). Populations of immature parasites were found in early August and September on *Solidago* in 1963, 1964, 1968 and 1969, and on weeds and other composites in 1963 and 1964. The incidence of parasitism of the *Lygus* hosts on *Solidago* in the Belleville district has varied from 0 to 12 parasites per 100 nymphs. These values may include larvae of *Euphoriana lygivora* which was not separable until 1969. Final instar larvae of *pseudopallipes* emerged from nymphs, and those of *pallipes* from teneral adults of *L. lineolaris*. Cocoons are formed in soil debris near the breeding plant of the host mirids. The diapausing adults overwinter in cocoons and are widely distributed since *Solidago* and *Aster,* especially, are common herbs interspersed between areas of cultivation.

The time of emergence of adults from overwintered cocoons is probably the most important factor isolating *pseudopallipes* from *pallipes*. In the insectary, in 1965, 3 adults of *pseudopallipes* emerged July 29; 6, August 1 to 3; 2, August 7; in 1966, 1, July 27; in 1967, 3, August 4; and 2, August 8. The number of emergents is low because of mortality of adults in cocoons. A possible reason for this may be insufficient moisture in the insectary after spinning up.

Though larvae of *pallipes* emerge from various mirids infesting legumes and grasses in a four-week period in June and early July, adults emerged in the insectary at about the same time in May: 3 adults, May 6; 5, May 9 to 12, 1966; 1, May 2; 3, May 14, 1967 (*Leptopterna dolobrata* (L.); 11, May 6 to 12, 1966 *(Adelphocoris lineolatus* (Goeze)); 1, May 14; 4, May 16 to 18; 3, May 22, 1966; and 3, May 10, 1967 *(Lygus lineolaris)*. Given adequate numbers, it is possible that differences related to larval emergence times might be evident. The data show, however, a separation in times of emergence between *pallipes* developing in first generation *L. lineolaris* and other mirids in May and June and *pseudopallipes* developing in second generation *lineolaris,* and *vanduzeei* in August and September.

Discussion

L. pseudopallipes was not previously recognized as a sibling species of *pallipes* because of morphological similarities, because much of the museum material is *pallipes,* collected in early summer, and because no biological information was available. The new taxon is ranked as a species because it is reproductively isolated from *pallipes* by phenological differences. If there were an overlap of adults, host and host plant preferences and the larger phallus of *pseudopallipes* might prevent interbreeding. Among the known *Leiophron* species, *pallipes* is the most plastic by its polyphagous parasitism and adaptation to different ecosystems (grass, forage legumes). The genesis of *pseudopallipes* from *pallipes,* or *vice versa* would require, primarily, a change in diapause period to adjust to the seasonal occurrence of mirid nymphs.

Euphoriana lygivora, New Species

Holotype — Female (CNC11588) Fuller, Ontario, Canada, latitude 44° 24'N, longitude 77° 25'W, reared August 14, 1969, from nymphs of *Lygus lineolaris,* collected August 21 to September 6, 1968 feeding on *Solidago canadensis,* C. C. Loan.

Length 2.7 mm. Reddish yellow; flagellar segments 1-4, bases of 5, 6 pale yellow, remainder dusky; frons immediately anterior to each ocellus dark reddish; propodeum dark brown; apical 0.2 of gaster behind tergite 1 light reddish; hind tibia except basal 0.3 light dusky.

Head nearly quadrate, slightly wider than long (22:19); vertex, cheeks, smooth, highly polished, glabrous; frons lightly shagreened; face shagreened, with short, thick pubescence; hair of clypeus sparse, erect, nearly as long as flagellar segment 1; frons unusually long, 1.3 times longer than face between antennal sockets and base of clypeus, level and flat 0.5 times its length behind antennal sockets then declivous to median ocellus; face flat, nearly vertical, eyes directed forward; antenna 15 segments (apical considered 1 segment); flagellum almost 2.0 times as long as width of head at eyes (20:11), as long as thorax and propodeum together; scape as long as segment 2 of flagellum; segment 1 of flagellum not as long as scape and pedicel combined (19:13), slightly longer than segment 2 (10:9) and 3 (10:8); apical segment more than 2.0 times as long as penultimate segment of flagellum, wider than segment 1 (4:3); lower face between eyes wider than long (4:3), as wide as frons is long; malar space 0.5 times as long as basal width of mandible, as long as pedicel, less than 0.5 times as long as flagellar segment 1; eye 1.4 times as long as wide; temple as wide as face between eyes, almost as wide as eye (8:9); POL not as long as OOL (2:3), slightly longer than space from median to lateral ocellus; vertex from occipital carina to lateral ocellus nearly as long as face between antennal sockets and base of clypeus, somewhat longer than OOL (11:9); anterior margin of median ocellus in line with posterior margin of eye.

Thorax not as wide as head (8:11); mesonotum generally glabrous, prescutal sutures indicated only by linear, shagreened areas converging posteriorly, area of convergence as wide as scutellar groove which is divided by 5 carinae; scutum punctulate medially; lateral lobes smooth, polished; scutellum rugulose; mesepisternum rugulo-aciculate posteroventrally, smooth and polished anterodorsally; hind tibia subequal to length of gaster behind tergite 1, longer than hind femur (28:23); propodeum almost as wide as long (9:10), rugulo-reticulate, sloping slightly behind, posterior face flat, nearly vertical; fore wing almost as long as body not including antenna and gaster behind tergite 1; radial cell very short, 0.25 times as long as stigma; first abscissa of radius punctiform; stigma 2.3 times as

long on wing margin as broad, base broadly hyaline; hind wing about as wide as fore wing; apical abscissa of basella much shorter than basal (7:12); nervellus not as long as marginal cilia. Gaster behind tergite 1 polished, glabrous except sparsely hairy at apex; tergite 1 subequally as long as propodeum, 3.0 times as long as wide at apical margin, apex slightly wider than base, laterally striate and medially somewhat rugulo-reticulate.

Paratype — One female swept Wallbridge, Ontario, latitude 44° 13'N, longitude 77° 30'W, August 18, 1969, from *Solidago canadensis,* C. C. Loan.

Remarks

E. lygivora runs to *uniformis* Gahan in the key to Nearctic species of *Euphoriana* (Loan, in press) by its completely obliterated cubitus. The following couplet summarizes the important differences between them.

Head immargined behind; eye not as wide as temple (5:7); malar space almost as long as basal width of mandible (5:6); mesonotum uniformly smooth, scutum and lobes not differentiated; propodeum reddish yellow, rugulose ..... *uniformis* Gahan.

Head distinctly margined behind; eye as wide as or wider than temple; malar space 2.0 times as long as basal width of mandible; scutum of mesonotum shagreened posteriorly, differentiated by lightly impressed prescutal sutures; propodeum dark brown, rugulo-reticulate ..... *lygivora* n. sp.

Biology

Braconid larvae were reared from nymphs of *L. lineolaris* swept from *Solidago* on August 18 to 21 and September 5 to 9, 1968. The cocoons were overwintered and a single specimen of *E. lygivora* emerged August 6, 1969. A second specimen was obtained August 18, 1969, sweeping *Solidago.* This specimen was the only one captured in about 12 hours of sweeping from August 10 to 26.

Acknowledgments

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INTRINSIC FACTORS CAUSING QUALITATIVE CHANGES IN POPULATIONS OF THE GYPSY MOTH

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Abstract

A change in the quality of individuals of the gypsy moth can be induced by several intrinsic and extrinsic factors. This change is expressed by a prolongation of instar I, an increase in larval activity during instar I, and an increase in the number of larval instars. The lag in development at instar I is associated with a longer prefeeding phase during which larvae are more active. These active larvae are more readily dispersed by wind. The behavioral shift can be induced during instar I by crowding, starvation, or cool temperature, or in the maternal generation by factors affecting the size of eggs. The most important effect of the qualitative change on the population biology of the gypsy moth is that it provides a mechanism for numerical self-regulation that operates rapidly to changes in population density, and is more efficient than if dependent solely on selection for expression. A new approach to control by prevention of the qualitative change is suggested, whereby populations would be maintained at sparse levels where suitable host plants prevail to suppress outbreaks and subsequent widespread dispersal of larvae.

Introduction

The work of Wellington (1957, 1960, 1962, 1965) on the western tent caterpillar, *Malacosoma pluviale* (Dyar), and of Chitty (1960) on the vole,

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Microtus agrestis, have shown the importance of changes in the quality of individuals in a population in determining the fate of that population. I wish to review some of my studies on the gypsy moth, *Porthetria dispar* (L.), to indicate the importance of a qualitative change on the population biology of this defoliating lymantriid.

Methods and Discussion

The studies conducted in the laboratory have utilized the wheat germ food of Leonard and Doane (1966). Unless stated otherwise, larvae were reared individually in plastic petri dishes in a controlled room at 23.5°C, 16 hours photoperiod per 24-hour day, and 40 to 60% RH.

During larval development, some larvae had more than the expected number of larval instars. Although it was generally known that the gypsy moth was polymorphic for the number of instars, the biological significance was not understood. In comparison of data from the larvae with an additional molt with "normal" larvae (Leonard 1966), it was apparent that the occurrence of an additional instar was more than just a biological curiosity. As one might expect, the larvae with the additional instar took longer to develop to adulthood, about four days longer at 23.5°C. Although the total rate of development was longer, the rate for the various instars differed from normals. Instar I took longer, and the last larval instar and pupal instar were shorter. Finally, the pupal weights were greater than in normal larvae, and fecundity is directly correlated with the pupal weight of females. Any one of these differences could have a marked impact on the population biology of the gypsy moth.

The occurrence of an additional larval instar is not restricted to the laboratory. Extra-instar larvae differ slightly in the size and coloration of the dorsal tubercles, and extra-instar larvae have been found in field populations (Leonard 1967).

How prevalent is the trait for additional larval instars? To date, 87 egg masses have been analyzed totally or in part. From these egg masses nearly 10,000 individuals have been reared to pupation or adulthood under controlled laboratory conditions (Leonard 1970a). In each of the 87 masses there have been some larvae with an additional molt. The percentages varied from 2 to 97% of the larvae from each mass having one or more additional molts. In most cases, larvae had one additional instar. A small percentage of the larvae had two or more additional instars.

Additional instars can be induced in at least two life stages of the gypsy moth, during instar I, or during the maternal generation via the egg. During instar I, additional molts have been induced by cool temperature (Leonard 1970a), by crowding (Leonard 1968), or by starvation (Leonard 1970b). All of these factors delayed the rate of development, and undoubtedly influenced the nutrition of the larvae. Larvae reared throughout instar I at 19.5°C, took about twice as long to complete the instar as those reared at 23.5°C, and the number of larvae with an additional molt at the cooler rearing temperature during instar I was significantly higher. Larvae crowded during instar I also took longer to complete instar I, and the percentage of extra-instar forms was larger. An increase in larvae with an additional molt in crowded cultures has also been noted in the armyworm, *Leucania separata* by Iwao (1962). Gypsy moth larvae starved in instar I on days 1 and 2, or days 3 and 4, or days 5 and 6 had an increase in the percentage of additional molts. Such periods of starvation during instars II, III, or IV did not affect the number of subsequent molts.

The variation in the percentage of extra-instar types between egg masses suggests that there is some maternal influence. The last eggs laid by females are

smaller (Leonard 1970a). These smaller eggs, thought to be deficient in yolk, are the last eggs produced by the female ovaries. The reduction in the amount of nutrients available for inclusion in eggs is a function of events which occur in later larval instars. Thus, events in the previous generation can influence the number of larvae with an additional instar in the next generation.

What is the impact of this qualitative change on the population biology of the gypsy moth? The most important element of the change is the prolongation of instar I. This is a critical stage in the life history, for this species disperses as instar I larvae. Female moths are flightless, and contribute nothing to dispersal. The wandering of late instar larvae can be measured in meters, but instar I larvae are capable of being carried for miles by the wind. It would appear that factors prolonging the duration of instar I will increase the possibilities of dispersal, but this is only partially true. It is the behavior of larvae which has the most pronounced effect on the occurrence of dispersal. Normally, when larvae reach suitable food after hatch, they increase their weight on feeding, and remain on the leaf, usually on the underside, attached to a sparse mat of silk. The inactive, fed larvae are not readily dislodged, even in strong winds (Leonard *in press* a). Few of the airborne larvae which have been trapped have the distended bodies characteristic of larvae which have fed.

Larvae which do not find suitable food become more active, are easily irritated, and readily spin down on silken threads (Leonard 1967). These larvae are readily carried off by the wind. Active larvae which are not hanging on threads of silk will arch their bodies when wind is blown over them, thus releasing their points of attachment with the substrate. If the wind is of sufficient velocity these larvae will be blown away.

The prolonged instar I of larvae which will undergo an additional molt is a reflection of a longer prefeeding phase during which the change in larval activity can occur. In dense populations in nature many larvae do not settle and feed, even when food is readily available and abundant. These larvae remain active, and constitute the majority of larvae being dispersed.

Wellington and Maelzer (1967) showed that the behavioral types of larvae of the western tent caterpillar were associated with the nutritional levels of eggs. There appears to be an analagous situation in the spruce budworm, as shown by Campbell (1962, 1966). Thus, the situation in the gypsy moth is not unique.

It is interesting to contrast the condition in the western tent caterpillar with that in the gypsy moth. In the tent caterpillar, the nutritively deficient eggs yield sluggish larvae which have a higher incidence of additional instar forms (Wellington 1957). These sluggish forms do not contribute to dispersal, rather, the active components of the population produce the most vigorous fliers. In the gypsy moth, deficient eggs yield larvae which do not readily settle and feed, and are more readily dispersed. This provides the gypsy moth with a means of reacting to changing environmental conditions, particularly increasing population densities, both more rapidly, and more efficiently than if this self-regulating mechanism was under more strict genetic control and dependent on selection.

The population flushes so characteristic of the gypsy moth appear on the surface to be deleterious to this species, for they ultimately result in dramatic crashes when food sources are depleted. I would suggest that these flushes are a necessary event in the biology of the gypsy moth, providing a mechanism for insuring dispersal and genetic mixture. If one can visualize a hypothetical population in an area where suitable host plants prevail, one would anticipate that the population size would increase, with the rate of growth dampened by various biotic and abiotic factors. As the population density increases, there comes a point where larvae are stressed and these larvae produce females which

lay eggs with reduced food reserves. The larvae emerging from these eggs will not readily settle and feed, but remain in an active state which greatly increases their changes for dispersal by wind. Enough larvae will remain in the area, however, to cause the depletion of foliage, with the resultant population crash. Before this crash occurs many of the larvae have been dispersed. Thus, population flushes can be advantageous to insure dispersal and genetic recombination, and may have evolved with the loss of flight in female moths.

It would be of interest to know at what density nutritively deficient eggs will be produced. Presently, I feel that it is the density at which there is a change in the diel periodicity of larval activity. Throughout the first three instars, gypsy moth larvae feed in the early morning, but at instar IV there is an abrupt change in this behavior (Leonard *in press* b), and larvae begin feeding in the evening, and remain quiescent during the day. At high larval densities, this diel periodicity changes, and larvae are active both day and night. I feel that it is these active larvae which produce the smaller eggs, for they probably spend less time feeding, and their wandering behavior utilizes food reserves which would normally be deposited in eggs. This shift in diel periodicity frequently occurs before there is any obvious sign of lack of available food.

What is intriguing to me is that this change in diel periodicity, the regulation of the amount of proteid yolk supplied the eggs, and the additional larval molt could all be controlled by the same hormonal system, the brain-corporus allatum-prothoracic gland system. Certainly, molting is controlled by this hormonal system, and DeWilde (1964) reviews work showing that the corporus allatum affects the amount of proteid yolk supplied the trophocytes during oogenesis as well as affecting feeding behavior. Wellington and Maelzer (1967) treated pupae of the western tent caterpillar with a mimic of juvenile hormone, and obtained eggs deprived of nutrients.

The occurrence of a density regulated mechanism to induce dispersal in the gypsy moth presents a possibility of an approach to control different than that now used. If population numbers could be kept below those levels where the effects of density induce dispersal, then dispersal might be suppressed, and the chance of widespread epidemics reduced. Such a strategy would necessitate monitoring populations of the gypsy moth, but only in areas where favored host plants predominate, mostly on the higher elevations. The point at which control measures would have to be applied would be below that level where noticeable defoliation would take place. Thus, the present concept of control, which entails aerial spraying of epidemic populations to prevent defoliation, would be altered to an approach to manage sparse populations to prevent their buildup. In managing sparse populations, a high percentage kill would be disadvantageous since a reservoir of natural control agents would be useful to maintain. For example, the short residual insecticides which are now being used provide marginal control in outbreak situations might be extremely useful against sparse populations. The survivor populations in the sprayed area would serve as hosts of biotic control agents, facilitating maintenance of these agents in the population. In addition to short residual insecticides there is a variety of biotic and abiotic agents already known which could be employed, either singly, or in concert, to test their effectiveness in maintaining gypsy moth populations at sparse levels.

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AN ANNOTATED LIST OF MOSQUITOES OF SOUTHEASTERN ONTARIO

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Abstract

A list of the Culicidae and Chaoboridae collected within a 50-mile radius of Belleville, Ontario, includes 35 culicids and 6 chaoborids. The general ecological background of the area is discussed and illustrated and data are tabulated on the habitats, abundance and behavior of 26 species. Collection points are indicated on two maps.

Introduction

Detailed findings on the ecology of mosquitoes in eastern Ontario were published by Beckel and Atwood (1959) and West and Hudson (1960). The present paper supplements these contributions by bringing together information on the Culicidae and Chaoboridae of the district around Belleville, Ontario (44° 10'N — 77° 23'W), including previously unpublished data. It is hoped that this list can serve as a base line for behavioral and ecological studies in this area and also help clarify changes in species composition and populations brought about by agricultural methods, urban development, and pollutants.

Sources

Much of the information on the mosquito fauna of the district resulted from four surveys. The first, in the spring of 1937, by Wishart (1937) (Figure 3) was a part-time project to determine whether control measures were desirable and practical in Belleville and vicinity. The second was initiated in 1944 by the Army Medical Services, Ottawa, to investigate the distribution of malaria vectors near hospitals and prisoner of war camps. This was done at military and/or air force establishments at Kingston, Trenton, and Peterborough (Wishart and James, 1945). The third was begun in 1964 by Belton to determine the number of species and population density of male mosquitoes in Belleville and at the Institute field station near Chatterton, some 10 miles north of Belleville. Finally, in 1965 and 1968, Maw, and Maw and James undertook to resurvey breeding habitats in the Belleville area. Additional collections and observations on mosquitoes were made by all these authors in the course of other aspects of research on biting flies from 1937 to the present time. Included also are records based on specimens in the Canadian National Collection, Ottawa and a few records from Trenton given by Steward and McWade (1961).

The specimens were collected over a period of 67 years, from 1901 to 1968, from sites within 50 miles of Belleville, mostly in Hastings and Prince Edward Counties (Figure 4).

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Ecology of the Region

Physiography

The physiography of the area considered in this study (within a 50-mile radius from Belleville) differs strikingly in the north on formations of the Precambrian Shield from that in the south where there is an overlay of limestone of the Trenton and Black River series of the Ordovician period. The basic limestone plain can be subdivided into six regions (Figure 1) (Chapman and Putnam, 1966), all of which are the products of glaciation, the southwestern ones having been altered by inundation during late Pleistocene times by Lake Iroquois. The six regions are as follows:

1. *Iroquois Plain:* The plain lies for the most part between the south slope of the Oak Ridges Moraine and the present shore of Lake Ontario. At Trenton it swings inland to include large areas of the Trent Valley. The plain deposits are composed of coarse sand, fine sand, and silt. The Trent Valley section is made up of wave-washed hillsides or boulder pavements with the low areas containing layers of stratified silt. In general this section merges easily into the Peterborough Drumlin Field. The drumlin and clay-flat formations are evidence of this.

2. *South Slope:* This is the south slope of the Oak Ridges Moraine where streams flowing down the slope have cut sharp valleys and gullies in the till. Bare gray slopes where soil is actively eroding are common. The underlying rock is Trenton limestone and the material in the drift is calcareous mixed with some importations by the glacier. The eastern part is thickly covered by big drumlins, and in Northumberland County fine sand and silt are found on the surface of the till up to a depth of 6 to 8 feet.

3. *Oak Ridges Moraine:* The moraine extends from the Niagara Escarpment to the Trent River. Its surface is hilly with typical end moraine knob-and-basin relief. The hills are generally composed of sandy or gravelly materials through which water drains vertically, moving laterally only when it reaches less pervious beds and reappears as springs along the slopes of the moraine.

4. *Peterborough Drumlin Field:* For the most part the rock underlying this region is Trenton limestone. The drift varies considerably in depth, being thin on the limestone plains to the north and thicker towards the south. The till contains boulders of Precambrian origin, many being 2 and 3 feet in diameter. The drumlins are composed of calcareous till, and the drumlin and clay-flat landscape is a striking feature. Generally the whole area is typical of intensely drumlinized areas being characterized by stoniness, steep slopes, and wet swampy hollows.

5. *Dummer Moraines:* The underlying bedrocks are mostly of the Black River series with some overlay by the Trenton. The limestone terminates on the north in an escarpment 25 to 75 feet in height and this escarpment is the demarcation zone between the Precambrian Shield and the southern limestone plain. The surface of the moraine is extremely rough with bouldery areas interspersed with swamps and tracts of bare limestone. Most of the morainic ridges are quite low.

6. *Napanee Plains:* The region is a flat-to-undulating limestone plain mainly of the Black River series from which most of the overburden has been stripped by glacial action and erosion. While the soil is only a few inches deep over much of the region, some deeper till occurs in the stream valleys and toward the north. A few scattered drumlins are found throughout the plain, and often toward the south shallow deposits of clay can be found, especially near Belleville, Stirling, and Desoronto, and in north Prince Edward County.

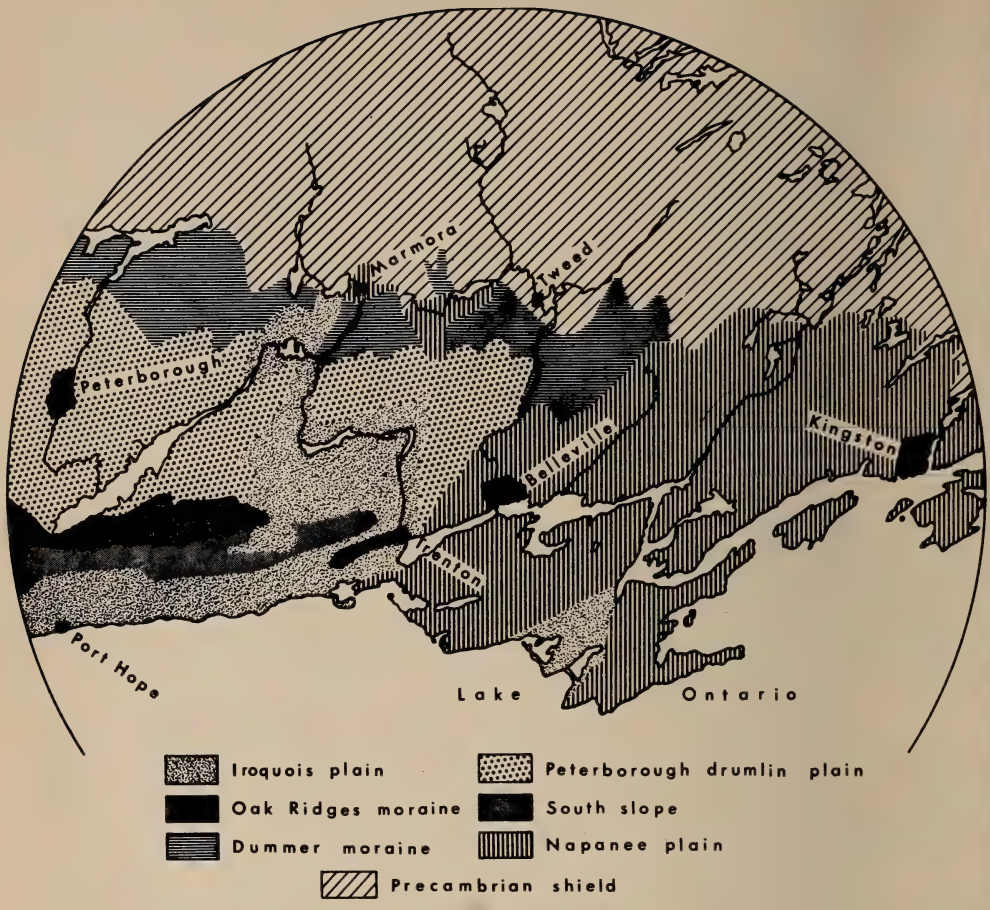

FIGURE 1. Physiography of the collection area within a 50-mile radius of Belleville

Forest Regions

Most of the material found in the following notes has been summarized from Rowe (1959).

The original forests of the Belleville area are classified as the Great Lakes — St. Lawrence Region of the Tolerant Hardwoods Division. The extreme easterly limits of the Deciduous Region may extend into the area included in this survey especially along Lake Ontario and the lowlands surrounding the western end of the Bay of Quinte and lower reaches of the Trent and Moira Rivers. Most of the good land has long since been cleared for farms, and forests on poorer but accessible lands have been clear cut so that the natural forest vegetation has been largely reduced to farm woodlots and remnant stands on the poorer, rocky, inaccessible sites. Much marginal and abandoned farm land has recently come under the jurisdiction of conservation authorities and has been reforested, often with the rapidly-growing red and Scotch pine. Burned areas are usually reclaimed by natural invasion of aspen, birch, and other rapidly-growing, shade-intolerant species.

The Great Lakes—St. Lawrence Region is usually divided into several sections of which only parts of the Huron-Ontario (L1), middle Ottawa (L4c) and

Georgian Bay (L4d) concern us (Figure 2). The boundary between the Huron—Ontario section and the others coincides with the contact zone between the Ordovician limestone plain and the granites of the Precambrian Shield. The boundary between the Georgian Bay and Middle Ottawa Sections is less distinct but generally follows the 32-inch isohyetal line, the main difference being that white spruce is common on sand flats and other coarse textured soils in the Georgian Bay Section whereas in the Middle Ottawa Section white pine is usual on such sites.

1. *Huron-Ontario Section:* Sugar maple and beech are common over the whole area where there are rich bottom lands and moist, well-drained slopes and ridges. Associated with them and running up low sandy slopes or gravelly ridges and hillsides are found basswood, white ash, yellow birch, red maple, and red, white, and bur oaks. Hemlock, white pine, and balsam fir are found on rich loams and sandy soils along with sugar maple and yellow birch. Scattered throughout on moist rich soils are aspen, butternut, hickory, ironwood, and black cherry. Blue beech, silver maple, slippery and white elm, and black ash can be found locally on river bottom and swamp sites. Eastern white cedar and the occasional stands of tamarack and scrub white spruce are present in swampy depressions. After fires, aspen and white birch often form secondary communities.

FIGURE 2. Forest regions within a 50-mile radius of Belleville

In the south, red cedar or juniper, and white cedar occur in fairly pure stands on the dry shallow soil where they invade old pastures. Hawthorn in varying amounts is also found.

2. *Middle Ottawa Section:* The upland forest is a mixture of sugar maple, beech, yellow birch, red maple, and hemlock with white pine and red pine characterizing dry ridges and sand flats in association with jack pine. Throughout are varying amounts of white spruce, balsam fir, aspen, white birch, red oak, and basswood. Hardwood and mixed-wood swamps are common in which eastern white cedar, tamarack, black spruce, black ash, red maple, and elm are found. In the south are scattered a few butternut, bur oak, white ash, and black cherry.

3. *Georgian Bay Section:* Sugar maple, beech, basswood, yellow birch, hemlock, white pine, red maple, and white ash, the most important trees, form mixed stands on the uplands. White spruce is common on sand flats and other coarse-textured soils. In the south, swamp stands of red maple, black ash, and cedar are present.

Climate

While the climate of southern Ontario is usually stated to be of the modified humid continental type, a number of different types of climate merge in this region. The area lies in the path of the most frequent occurrence of cyclonic storms, and the Great Lakes greatly modify both temperature and moisture relationships (Putnam and Chapman, 1938). In the area surrounding Belleville the mean annual temperature ranges from 44°F in the south to 42°F in the northern part. The extremes recorded for the city of Belleville over a period of 100 years are a low of –39°F in February and a high of 104°F in July. The mean annual frost-free period ranges from 130 days to 145 days with the last frost being about May 15 and the first about September 30. The start of the growing season (mean date when mean temperature rises above 42°F) is April 15, and the end of the growing season about October 31. In the sheltered areas under dense foliage in a cedar swamp the melting of ice and the growing season are considerably delayed in spring, and early ice may linger longer in the day after cold nights in autumn.

The annual precipitation ranges from 32 inches at Peterborough to 35 inches at Kingston, Belleville receiving 33 inches. The average summer precipitation, between May and September, is between 14 and 15 inches. The annual snow fall is about 80 inches, arriving in mid-November, and the last day of cover being April 1.

Methods

In the 1937 and 1944-45 surveys, breeding habitats were scouted for larvae early in the season and collection points marked on a grid map. Weekly samples of larvae and/or pupae were reared in the laboratory to the adult stage and other adults were netted. Resting anophelines were collected in culverts, under verandahs or in nail kegs placed in possible habitats. All adults were identified in Ottawa by Dr. C. R. Twinn.

A light trap was operated by Belton at Chatterton, from early May until November in a clearing in mixed woodland. Samples of adults were collected daily. Identification was made by examination of the male terminalia, but doubtful records or specimens involving new records for the district were submitted to the Entomology Research Institute, Ottawa, for confirmation.

Systematic collections of mosquito larvae and pupae throughout development were made by James annually when investigating mosquito predators at Chatterton and Cordova Mines. Most of the specimens were preserved in alcohol, but samples were also reared and the adults sent to specialists in Ottawa for determination.

In the 1965 and 1968 Belleville surveys (Figure 3), some larvae in each collection were reared to the fourth instar and then preserved; the remainder were allowed to reach the adult stage. After pinning, the specimens were dried in deep freeze and later identified.

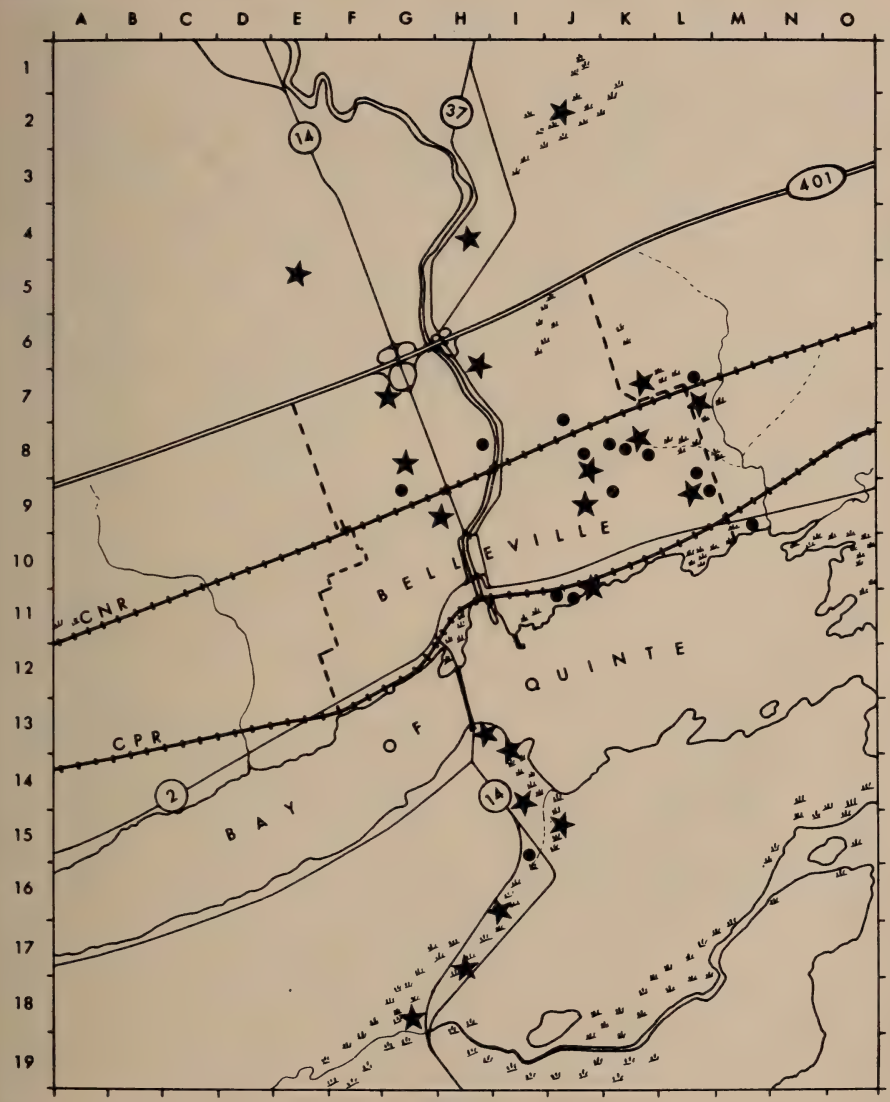

FIGURE 3. Mosquito collection points in Belleville and environs:

★ Wishart

● Maw, Maw and James 1965-68

The Mosquito Fauna

Data on 35 species of Culicidae and 6 of Chaoboridae collected in the Belleville district are shown in Table I. The order of taxa follows that of Stone *et al* (1965). The names of the collectors or authors are abbreviated as follows:

FIGURE 4. Mosquito collection points within a 50-mile radius of Belleville, 1901-68

B.....Belton
J.....James
L&W.....Laing and Welch
M.....Maw
M&J.....Maw and James
S&M.....Steward and McWade
V.....Vockeroth
W.....Wishart
W&J.....Wishart and James

Other abbreviations used in Table I are:

A(AA).....adult(s)
assoc.....associated
C.N.C.....Canadian National Collection, Ottawa
coll.....collected
com.....common
det.....determined
E(EE).....egg(s)
L(LL).....larva(e)
l.t.....light trap
P(PP).....pupa(e)
perm.....permanent
Res. Inst. .....Entomological Research Institute, Belleville
rk.....rock
seep. .....seepage
uncom.....uncommon
v.....vernal
wood.....woodland

TABLE I. Mosquitoes collected in the Belleville district

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
CULICIDAE					
Anopheles earlei Vargas	1944	Grafton (W&J)	AA(2)	Culvert	
		Trenton (W&J)	AA,1.t.	Culvert over small stream	
	1945	Kingston (W&J)	AA,1.t.	Nail keg; under verandah	Residential suburb
		Peterborough (W&J)	A	Culvert	Residential suburb
	1964-67	Belleville (B)	AA,1.t.		♀♀also hibernating in Res. Inst., June-Oct.
		Chatterton (B)	AA,1.t.		Agricultural terrain with extensive woodlots and undrained depressions
Anopheles punctipennis (Say)	1944	Belleville (J)	A	Cellar	
		Brighton (W&J)	A	Culvert	
		Grafton (W&J)	AA(2)	Culvert	
		Kingston (W&J)	AA(11)	Culvert	Marsh, one mile west of Cataraqui R.
		Madoc (J)	A		Coll. Sept.
		Trenton (W&J)	AA(3),1.t.		
			LL	Myer's Creek	Coll. among marginal vegetation
	1945	Kingston (W&J)	AA(78)	Culverts; nail kegs; under verandahs	Residential suburb
			LL	*Typha* marsh, Little Catarqui R.	Residential suburb
		Peterborough (W&J)	AA(61), l.t.	Marsh, culverts	Residential suburb
			LL	Meade Creek	Residential suburb

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1945	Trenton (W&J)	AA(10)	Culverts	Flat terrain of airport drained by small streams and ditches
			LL(82)	*Typha* stand with *Lemna-Sagittaria* association, Myer's Creek	
	1955	Cooper (J)	LL(2)	Rk. pools, Black R.	
	1959	Chatterton (J)	LL(5)	V. wood. pools	Coll. July 21; assoc. with *Aedes vexans*
	1960	Cordova Mines (J)	LL	Rk. pools, Crowe R.	Coll. Sept. 7; assoc. with *Aedes atropalpus*
	1961	Cordova Mines (J)	LL(61)	Rk. pools, Crowe R.	Assoc. with *Aedes atropalpus* and *Culex territans*
	1962	Cordova Mines (J)	LL	Rk. pools, Crowe R.	Coll. June 1-Oct. 2
	1964	Chatterton (J)	AA	V. wood. pools	Biting Apr. 26, evening
	1964-67	Belleville (B)	AA, l.t.		Coll. June-Oct. Most numerous of 4 *Anopheles* species trapped
		Chatterton (B)	AA, l.t.		
Anopheles quadrimaculatus Say	1944	Barriefield (J)	A	Culvert	
		Belleville (W)	AA(4)		Coll. Sept. 5-30
		Brighton (W&J)	A(5)	Culverts	Coll. Sept. 6
		Cobourg (W&J)	AA(17)	Culverts	Coll. Sept. 6
		Colborne (W&J)	AA(5)	Culverts	Coll. Sept. 6

		Kingston (W&J)	AA(19)	Marsh, Little Cataraqui R.; Barriefield and Navy Bay	Coll. Aug. Resting AA beneath verandah, Hospital "A"; 4 AA in l.t.
		Madoc (W)	AA(16)		Coll. Aug. 19
		Trenton (W&J)	AA(44) LL	Culverts Myer's Creek	Coll. July 15-Sept. 30 Among marginal vegetation
	1945	Kingston (W&J)	AA(71)	Little Cataraqui R.; Culverts	Fewer AA at Hospital "A" than in 1944
	1945	Peterborough (W&J)	AA(12), (2)l.t.	Culverts, Meade Creek	Suburb
		Trenton (W&J)	AA(32), LL	Culverts, Myer's Creek and stream at Bayside with grass-rimmed pools near Bay of Quinte	AA coll. July 15-Sept. 30
	1964-67	Belleville (B)	AA,l.t.		Hibernating ♀♀ coll. Res. Inst. Aug.-Oct.
Anopheles walkeri Theobald	1944	Kingston (W&J)	AA(5), (24)l.t. LL	*Typha* marsh, Cataraqui R. *Typha* marsh, Cataraqui R.	AA coll. on wing
		Trenton (W&J)	AA(25),l.t.		
	1945	Kingston (W&J)	AA(71) AA(31),l.t.	*Typha* marsh, Cataraqui R.	Suburb
		Peterborough (W&J)	A, culvert AA(7),l.t.		Suburb
		Trenton (W&J)	AA(3), culverts AA(176),l.t.	*Typha* marsh	AA may be attracted by air station illumination
	1961	Kingston (S&M)	A		
	1964-67	Belleville (B)	AA,l.t.		
		Chatterton (B)	AA,l.t.		

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1968	Belleville (M&J)	LL(4)	*Typha* marsh (H-8); willow scrub pools (J-8); open pools (K-9)	Coll. July 8-10
Uranotaenia sapphirina (Osten-Sacken)	1945	Kingston (W&J)	A		
		Trenton (W&J)	A		
	1965	Belleville (B)	A,l.t.		Coll. Sept. (♀)
	1967	Belleville (B)	A,l.t.		
Culiseta inornata (Williston)	1945	Trenton (W&J)	A	Culvert	
	1965-67	Chatterton (B)	AA,l.t.		Coll. June-Nov.
		Chatterton (B)	EE	Res. Inst. field station. Artificial ponds lined with dark plastic	Coll. July
Culiseta minnesotae Barr	1964	Bellevile (B)	A,l.t.		(♂)
	1965-67	Chatterton (B)	AA,l.t.		Coll. July-Oct. Not uncom. Not previously recorded in the district (Belton and Galloway, 1966)
Culiseta morsitans (Theobald)	1961	Cordova Mines (J)	LL(9), PP	V. wood. pool in clearing	Coll. May 29; PP coll. June 19. Assoc. with LL of *Aedes excrucians*
	1965-67	Chatterton (B)	AA,l.t.		Coll. July-Nov. Commonest of this genus at l.t.

Mansonia perturbans (Walker)	1945	Kingston (W&J)	A		Unpublished record
		Trenton (W&J)	AA(6)		Coll. July 13
	1964-67	Belleville (B)	AA,l.t.		In 1967, this species was a troublesome and persistent biter in July and Aug.
	1965	Chatterton (B)	A,l.t.		Coll. Aug. (♂)
	1967	Chatterton (B)	AA,l.t.		Coll. June-July. More common than in 1965
Aedes abserratus (Felt and Young)	1961	Halloway (J)	L	Seep. pool among mosses	
	1965	Belleville (M)	AA	Herchimer Ave. swamp, west end (J-8); Eastminster Church under eaves	♂♂
	1965-67	Belleville (B)	AA,l.t.		Coll. occasionally. ♂♂ swarming over white posts and similar markers; assoc. with chironomids
		Chatterton (B)	AA,l.t.		Com. May-July
	1968	Belleville (M&J)	LL(32)	Open grassy pools (I-15); willow scrub pools (J-8); *Typha* marsh (M-9)	Coll. Apr. 23-June 10
		Chatterton (M&J)	L	V. wood. pool, field station	Coll. May 1
Aedes atropalpus (Coquillett)	1954	Plainfield (J)	LL(5)	Shallow rk. pool, Moira R.	AA emerged in lab. June 23-29 Not taken in l.t. at Chatterton or Belleville
	1955	Cooper (J)	LL(8)	Rk. pools, Black R.	

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1958	Roslin (J)	LL(4)	Rk. pools, Moira R. near Chisholm's Mill	AA emerged July 28
		Cooper (J)	LL, PP	Rk. pools, Black R.	Coll. June 25, uncom.; larvae of predator, *Laccophilus maculosus* Germ. abundant
	1960	Cordova Mines (J)	AA(2), LL(21), PP(10)	Rk. pools, Crowe R.	♀♀biting near pools June 6-8 LL assoc. with *Anopheles punctipennis*
	1961	Cordova Mines (J)	LL(9), PP(8)	Rk. pools, Crowe R.	Coll. June 7-Oct. 12. Assoc. with LL of *Culex restuans* and *C. territans* (James, 1964)
	1962	Cordova Mines (J)	LL(702), PP	Rk. pools, Crowe R.	Coll. June 4-Oct. 4. Used in study of predators (James, 1965)
Aedes aurifer (Coquillett)	1952	Marmora (V)	LL		C.N.C. Coll. May 21-July 4; ♂,♀♀(2)
	1965-67	Chatterton (B)	AA,l.t.		Coll. May-June, not uncom.
Aedes barri Rueger	1961	Cordova Mines (J)	LL(4)	V. wood. pools with flooded sedges, near pool 2 (James, 1966)	Coll. with LL of *Aedes excrucians* and *A. stimulans*
	1968	Chatterton (M&J)	LL(6)	V. wood. pools, field station	Coll. May 1
Aedes canadensis (Theobald)	1906	Trenton	A		C.N.C. coll. Aug. 5, probably by J. D. Evans, a contributor to the *Canadian Entomologist*. Det. E. Hearle (♀)

	1951	Chatterton (J)	LL(10)	V. wood. pools	
	1954	Chatterton (J)	LL(2)	V. wood. pools	
	1960	Belleville (J)	PP	Grass-lined pool in marsh (J-8) north from Lambert Drive	
		Chatterton (J)	EE(5)	V. wood. pool site, with ground cover of mosses and *Rhus toxicodendron* L.	In soil samples coll. Oct. 14 at Res. Inst. field station
	1961	Cordova Mines (J)	LL(9)	V. wood. pool and seep. pool near Fish Hatchery	Coll. May 29-31
		Halloway (J)	LL(8)	Seep. pools in moss	Coll. May 30-June 7
	1965	Belleville (M)	LL, PP	Shallow pools with *Typha* stand and deep moss over limestone (H-8)	Coll. May 21, Lightfoot Construction Co. property. AA emerged May 25.
	1965-67	Chatterton (B)	AA,l.t. LL	V. wood. pools	Not uncom. June-Sept. June-July
	1968	Belleville (M&J)	LL(7)	Open, grassy pools (I-15); willow scrub pools (J-8). *Typha* marsh (M-9)	Coll. Apr. 23-June 10
		Chatterton (M&J)	L	V. wood. pool, field station	Coll. May 1
Aedes cinereus Meigen	1952	Marmora (V)	AA		C.N.C. coll. June 3 and July 12, (♂ and ♀)
	1961	Cordova Mines (J)	LL	Seep. pool	Coll. May 31, near Fish Hatchery

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1965	Belleville (M)	LL(20) A	Herchimer Ave. marsh (J-8); small pools in *Typha* marsh (I-11); shallow pools in *Typha* marsh with limestone underlay (M-9)	Coll. May 20-31
	1965-67	Belleville (B)	AA,l.t. LL	Herchimer Ave. marsh (J-8)	Coll. June-Sept.
		Chatterton (B)	AA,l.t.		Com. May-Oct.
	1968	Belleville (M&J)	LL(21)	Willow scrub pools (J-8), (K-9); *Typha* marsh (M-9)	Coll. Apr. 17-June 10
Aedes communis (DeGeer)	1937	Cannifton (W)	AA	Wood. pools	On wing, May 20
		Rossmore (W)	AA	Open wood. pools	On wing, Apr. 29
	1961	Cordova Mines (J)	LL(15)	Tamarack-black spruce bog, in pools enclosed by mossy hummocks	Coll. May 11. Assoc. with LL of *Aedes trichurus* (James, 1966)
			LL(17), PP(10)	Large, open pool near tamarack-spruce bog	Coll. May 11-18
			LL(2)	Deep v. wood. pool	Assoc. with LL of *Aedes stimulans*
		Chatterton (J)	E	V. wood. pool site	Larva originated from egg in soil sample
	1965-67	Chatterton (B)	AA,l.t.		Uncom. June-July

Aedes diantaeus Howard Dyar and Knab	1961	Cordova Mines (J)	LL(2)	V. wood. pool in clearing	
	1966	Chatterton (B)	AA(2),l.t.		Coll. July 1-3. Rare
Aedes dorsalis (Meigen)	1937	Belleville (W)	LL(50), PP(31)	Perm. marsh near Herchimer Ave. (K-8)	Coll. May 5, assoc. with *Aedes stimulans*. Adults flying in June
	1965	Belleville (M)	LL(21)	Pools in mosses over limestone (H-8); also in cracks in limestone lined with moss	Coll. May 2. Lightfoot Construction Co. property. Breeding site in east Belleville not found
		Belleville (B)	AA,l.t.		(3♀♀) l.t. operated at sewage disposal plant (I-11). None caught in Chatterton l.t.
	1968	Belleville (M&J)	L	Mossy pool (H-8)	Coll. Apr. 23
Aedes excrucians (Walker)	1937	Belleville (W)	AA(3), LL	Open marsh (G-8); perm. marsh (K-8)	Coll. May 3-5. Assoc. with LL of *Aedes dorsalis*
		Rossmore (W)	LL(6), AA(24)	V. wood. pools (G-16, H-13-16)	
	1951	Chatterton (J)	LL(8)	V. wood. pools	Coll. May 20
	1954	Belleville (J)	LL(7)	Marsh (K-8)	Coll. Apr. 23
	—	Trenton (S&M)			
	1961	Cordova Mines (J)	LL	Shallow v. pool in clearing	
	1964-67	Belleville (B)	LL; AA,l.t.	Breeding pools west of Herchimer Ave. (J-8)	LL coll. May-June. AA coll. June-Aug., later than *Aedes stimulans* in both Belleville and Chatterton. A persistent and painful biter

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1965	Belleville (M)	LL, AA	Breeding in wood. pools (K-8) heavily charged with organic matter	Coll. LL May 31
	1968	Belleville (M&J)	LL(69)	Open, v. pools (G-9, H-8, K-9); *Typha* marsh (I-8, J-8, L-7, M-9); ditch Newberry & St. Paul Sts. (I-11); willow scrub pools (K-8)	Coll. Apr. 16-26
Aedes fitchii (Felt and Young)	1937	Belleville (W)	LL(4), P	Swampy fields, Herchimer Ave. (J-8); perm. marsh K-8)	Coll. May 5; P, May 15
	1960	Belleville (J)	LL(3)	Open V. pool 2.5 miles east of city, north of Highway 401	Coll. May 19
			LL(2)	Semi-perm. open pool (L-7)	Coll. May 20
	1961	Cordova Mines (J)	LL	V. wood. pool in clearing	LL scarce; coll. Apr.-May
	1965-67	Belleville (B)	AA,l.t.		Coll. June-July. Not uncom. in l.t. at Belleville and Chatterton
	1968	Belleville (M&J)	LL(61)	Grassy pools (G-9); *Typha* marsh (I-8, L-7, M-9); willow scrub pools (K-8)	Coll. Apr. 16-26

Aedes implicatus (Vockeroth)	1937	Belleville (W)	LL	Marsh near Herchimer Ave. (J-8) and pools north of C.N.R. tracks	LL coll. May 4; AA, May 20-June 12. Originally identified as *Aedes impiger* (auct. nec Walk.) (Vockeroth, 1954). Adults biting in June
	1951	Chatterton (J)	L	V. wood. pool	Originally identified as *Aedes impiger*
	1952	Marmora (V)	A		Coll. May 21. In C.N.C.
	1954	Chatterton (J)	LL(5)	V. wood. pool	Coll. Apr. 29
	1965-66	Chatterton (B)	AA,l.t.		Uncom. in l.t. June-July
	1968	Belleville (M&J)	LL(3)	*Typha* marsh (L-7, M-9)	Coll. June 16-26
Aedes intrudens Dyar	1937	Belleville (W)	LL	Roadside ditch and marsh Cannifton; v. wood. pools (H-17)	AA generally distributed and within a radius of 5 miles; the commonest black-legged, biting species; coll. May 8-June 10; LL, May 4-8
	1954	Chatterton (J)	L	V. wood. pool	
	1961	Cordova Mines (J)	LL	V. wood. pool	
	1965-67	Belleville (B) Chatterton (B)	AA,l.t. AA,l.t.		Not uncom. May-June Not uncom. May-June
Aedes pionips Dyar	1965-67	Chatterton (B)	AA,l.t.		Coll. May-June, not uncom.
Aedes punctor (Kirby)	1937	Belleville (W)	AA(2)		Coll. May 26 at Wallbridge Point (L-13)
	1951	Chatterton (J)	LL(7)	V. wood. pools	Coll. May 5-7
	1961	Cordova Mines (J) Halloway (J)	LL(3) LL(2)	V. wood. pools Seep. pool at foot of hill	Coll. May 29 Coll. May 30

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1964-67	Belleville (B)	AA,l.t.		Not uncom. in l.t. May-July. This species observed forming compact swarms over contrasting elevated markers, dark fence posts; also over observer or white insect net in urban gardens and uncultivated pastures at Chatterton
		Chatterton (B)	AA,l.t.		Coll. June 10
	1968	Belleville (M&J)	L	Willow scrub pools (J-8)	
Aedes riparius Dyar and Knab	1964-67	Belleville (B)	AA,l.t.	Marsh (J-8)	Coll. May-July ♂♂ in compact swarms over branches of willow and small bushes surrounding a pool and could be reformed over a white insect net
	1965	Belleville (M)	AA	Herchimer Ave. marsh	Coll. May 23 from male swarm
	1968	Belleville (M&J)		Open grassy pools (G-9); mossy pools (H-8); willow scrub pools (J-8); v. wood. pools (L-9);	Coll. Apr. 22-June 10
			LL(53)	*Typha* marsh (M-9)	
Aedes sticticus (Meigen)	1901	Trenton	A		C.N.C. (♀) originally identified as *Aedes hirsuteron* Theobald by E. Hearle. Probably collected by J. D. Evans of Trenton

	1906	Trenton	A		C.N.C. (♀) originally identified as *Aedes hirsuteron* Theobald by E. Hearle. Probably collected by J. D. Evans of Trenton
Aedes stimulans (Walker)	1937	Belleville (W)	LL(44)	Wood. pools (G-8); marsh (H-17, J-2, J-8)	Coll. May 3-7. One of the most abundant species breeding in this area. Assoc. with larvae of *Aedes dorsalis* and *A. trichurus*
			AA(65)	Wood. pools and marsh (K-8)	Coll. May 7-June 25
	1945	Peterborough (W&J)	AA		Abundant
	1951	Chatterton (J)	LL(21), PP(14)	V. wood. pools, Sine's swamp	Coll. Apr.
	1953	Chatterton (J)	LL, PP	V. wood. pools, Sine's swamp	Coll. Mar. 25-May 5; PP, May 5-11
			AA		Coll.♂♂, May 9-18,♀♀, May 11-22. Larvae were tagged with radioactive phosphorus to identify predators (Baldwin, James, and Welch, 1955)
	1954	Belleville (J)	LL(8)	Marsh east of Herchimer Ave. (J-8)	Coll. Apr. 23
		Chatterton (J)	LL, AA	V. wood. pools, Sine's swamp	LL Coll. Apr. 8-13.♀♀ emerged in cage over pool May 13-20. A late hatch of larvae were prey of the chaoborine, *Mochlonyx velutins* (James, 1957).
	1955	Millbridge (J)	LL(10)	V. wood. pool	
	1956	Chatterton (J)	LL	V. wood. pools	Coll. Apr. 6. Other data on hatching, populations, and predators (James, 1961).
	1958	Chatterton (J)	EE	V. wood. pool sites, Sine's swamp	Eggs laid in soil along margins of pools (James, 1966)

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1961	Cordova Mines (J)	LL(17)	V. wood. pools	Coll. May 14-18. Assoc. with LL of *Aedes communis, A. barri,* and *A. diantaeus*
		Kingston (S&M)			
	1964-67	Belleville (B)	AA,l.t.	Herchimer Ave. marsh (J-8, K-8)	The abundant and well-distributed AA are the major biting nuisance in this area, from May to Aug.
		Chatterton (B)	AA,l.t.		Biting rates up to 60/min. at dusk in woods; ♂♂ formed fairly loose swarms under the outer branches of trees at margins of woods and in clearings. If this species swarms above a marker it is not an obvious one to the human eye, and black and white cards placed under swarms did not aggregate them. Up to 1000 AA can be coll. in a 1.t. on one night at the peak of their season
	1965	Belleville (M)	AA	Herchimer Ave.; Eastminster Church; garden, 97 Southview Ave.	Coll. May 23
	1968	Belleville (M&J)	LL(164)	Mossy pools (H-8); *Typha* marsh (I-8); drainage ditch (I-11); pools among scrub willow (J-8); *Typha* marsh (J-11, L-7, M-9); pools willow scrub (K-8); v. wood. pools (K-9, L-9)	Coll. Apr. 16-26
		Chatterton (M&J)	LL(11)	V. wood. pools Inst. field station	Coll. May 1

Aedes thibaulti Dyar and Knab	1967	Belleville (B)	A,l.t.		Coll. June 28 (♂) (Belton and French, 1967)
Aedes trichurus (Dyar)	1937	Belleville (W)	LL, AA	Wood. pools at H-17	AA within 5 mile radius of city, about as numerous as *Aedes intrudens* but seldom taken biting AA coll. May 7-14
	1951	Chatterton (J)	LL(5), AA(4)	V. wood. pools	
	1952	Marmora (V)	LL(33)	Marsh	C.N.C. reared to adult stage.♂♂ emerged May 7-21,♀♀, May 9-22
	1953	Chatterton (J)	LL(153) AA(623)	Large, V. wood. pool	Coll. Mar. 25-Apr. 30 AA emerged in cage over pool: ♂♂ May 7-16; ♀♀, May 8-18
	1954	Chatterton (J)	LL(108)	V. wood. pool	Coll. Apr. 6-13 Assoc. with *Aedes stimulans* in ratio of 1:3. First-instar LL were prey of *Mochlonyx velutinus* (James, 1957)
			AA(17)		AA emerged May 7-13
	1958	Chatterton (J)	EE	V. wood. pool sites	Coll. Sept.-Oct. Eggs laid in soil in marginal and sub-marginal pool sites (James, 1966)
	1961	Chatterton (J)	LL(292)	V. wood. pools at southern margin of Sine's swamp	Coll. Mar. 3-7 in water at 3°C. Earliest record of hatching in this district. Many larvae killed when pool margins refroze to bottom (James, 1962)
		Cordova Mines (J)	LL(17)	V. wood. pools	Coll. May 11-18. Assoc. with *Aedes communis* and *A. excrucians*. Not abundant

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1961-66	Chatterton (M)	AA	Res. Inst. field station	Diffuse swarms at margins of woods, with a definite circulating form similar to that described by Downes (1958) for *Aedes hexodontus* (Maw — personal communication)
	1964-67	Belleville (B)	AA,l.t.	V. wood. pools	LL seldom in pools outside of woods; assoc. with *Aedes stimulans*. AA common in early summer
		Chatterton (B)	AA,l.t.	V. wood. pools	
	1968	Belleville (M&J)	LL(8)	*Typha* marsh (I-8, L-8)	Coll. Apr. 16
		Chatterton (M&J)	LL(13)	V. wood. pools Res. Inst. field station	Coll. May 1
Aedes triseriatus (Say)	1961	Cordova Mines (J)	L	Pool in roadside ditch with rotting stumps	Identified as reared male
	1965-67	Chatterton (B)	AA,l.t.		Uncom. but specimens were trapped each year. Only one female was observed during the day, and bit readily
Aedes vexans Meigen	1937	Belleville (W)	AA	Open wood. pools	Adults were unusually early (Apr. 29) south of Rossmore; also collected in and north of city in May
	1945	Peterborough (W&J)	LL(80), PP	Shallow pool with grasses 0.4 mile N.W. Gen. Electric Co. plant	Coll. July 24

	Trenton (W&J)	LL(21)	Among grasses in open pond receiving waste from dye works, 2.4 miles west of R.C.A.F. hospital	Coll. Aug. 24
1954	Belleville (J)	LL	Marsh near Herchimer Ave.	Coll. Aug. 24
	Chatterton (J)	LL	V. wood. pool	Coll. Apr. 20
1955	Cooper (J)	LL(2)	Wood. pool in clearing	Coll. Aug. 22
1958-59	Chatterton (J)	EE	V. wood. pool sites, Sine's swamp, in soil	Larvae obtained by flooding soil samples containing eggs
1959	Chatterton (J)	LL	V. wood. pools	Coll. July 9. LL abundant but were unable to complete development before pools dried up (James, 1960)
1965	Belleville (M)	LL(19)	Shallow ditch, St. Paul and Newberry Sts. (I-11). Water polluted with wash-water effluent	Coll. May 20-21. Adults emerged May 28
1965-67	Belleville (B)	AA,l.t.		July-Oct. A major biting nuisance in late summer. In favourable years the arrival of *A. vexans* and *Mansonia perturbans* overlaps the departure of *A. stimulans*. Porch sitters are apparently inured to a low but steady 5-6 bites per evening from one or other of these species between mid-May and Sept. 1. The Res. Inst. receives few complaints
	Chatterton (B)	AA,l.t.		

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1968	Belleville (M&J)	LL(33)	Mossy pools Lightfoot Construction Co. property (H-8); *Typha* marsh (I-8, J-8); willow scrub pools (J-8); *Typha* marsh near Bakelite plant (M-9)	Coll. Apr. 16-Aug. 27
Culex pipiens Linnaeus	1937	Belleville (W)	LL	Rain barrels in Rossmore (H-13)	May possibly have been C. territans
	1945	Kingston (W&J) Peterborough (W&J) Trenton (W&J)	LL(17) LL(3) LL(8)		Identified in adult stage
	1955	Belleville (J)	AA(5)		Coll. in cool room Res. Inst.
	1962-67	Belleville (B)	AA,l.t.		Trapped consistently but never in large numbers with New Jersey traps (catch of females only approximately halved in the absence of light), June-Nov. Oviposited readily in rainwater tank and drums around the Res. Inst., particularly if organic content of water was high. Compact swarms observed over clothes posts in June and July. In Sept.-Oct. swarms were more frequently observed at and under the tips of tree branches and on cold evenings (10-15°C) swarms were found only under the eaves of houses, usually on the sun-warmed western side. Females engorged with blood were found in houses in the morning.

	1966-67	Chatterton (B)	AA,l.t.		Coll. occasionally
	1968	Belleville (M&J)	EE	Rain barrel (J-8)	Coll. Sept. 9
			LL(40)	Mossy pool (H-8); drain ditch (I-11); rain barrel (J-8)	Coll. July 8-July 9
Culex restuans Theobald	1958	Plainfield (J)	LL, PP	Seep. pools on limestone ledges, Moira R., by mill, Latta	Coll. June 19
			LL(10), PP(6)	Shaded pools on island in Moira R., 1.2 miles north of Latta	Coll. July 24
	1961	Cordova Mines (J)	LL(5), PP(2)	Seep. and rk. pools Crowe R.	Coll. May 31-June 27. Later than LL of *C. territans*; assoc. with LL *Aedes atropalpus* (James, 1964)
		Chatterton (J)	LL(6), PP(2)	Plastic-lined pond Field station	Coll. June 14-15
	1962	Cordova Mines (J)	LL(700)	Rk. pools Crowe R.	Coll. June 16, and tagged with radioactive phosphorus to identify predators (James, 1965)
		Chatterton (L&W)	EE, LL	Eggs laid in artificial ponds, field station	LL were prey of *Dolichopus gratus* Lw. (Laing and Welch, 1963)
	1964-67	Belleville (B)	AA,l.t.		Coll. June-Oct. Rare. This species was not recorded by Wishart (1937), perhaps because it was not distinguished from *Culex pipiens*. Not found in houses biting man
	1964-67	Chatterton (B)	AA,l.t.		Fairly common at l.t., June-Oct. This species oviposited readily in clean artificial and natural wood. pools at Chatterton, but was not found in similar pools with a high organic content in Belleville
	1968	Belleville (M&J)	(J-8) Willow scrub pools (J-8); rain barrel	LL(13)	Coll. June 10-July 8

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
Culex territans Walker	1937	Belleville (W)	LL(2)	Rain barrel, Coleman flats (H-9); possibly at Rossmore (H-13)	Coll. May 31
	1945	Kingston (W&J) Peterborough (W&J) Trenton (W&J)	LL, AA(20) LL(2) LL, AA(9)		
	1958	Millbridge (J)	LL(9), P	Semi-perm. pool, Highway 62	Coll. July 30 3.1 miles north of Millbridge. Assoc. with LL of *Chaoborus americanus*
		Plainfield (J)	LL	Seep. pool on limestone, Moira R.	Coll. July 24
		Roslin (J)	LL(17), PP(16)	Semi-perm. pool near stand of white cedar	Coll. 1.3 miles north of Chisholm's Mill, July 24
	1960	Cordova Mines (J)	LL(5), PP(2)	Rk. pool, Crowe R.	Coll. Sept 27 in roadside park 0.3 miles south of Fish Hatchery. Assoc. with LL of *Anopheles punctipennis*
	1961	Cordova Mines (J)	LL(11), PP(2)	Crowe R., deep rk. pool with high organic content	Coll. June 2-10. Assoc. with LL of *Aedes atropalpus* and *Anopheles punctipennis*
	1962	Cordova Mines (J)	LL(160)	Rk. pools, Crowe R.	Coll. July 26. LL tagged with radioactive phosphorus to identify predators (James, 1965)
	1964-67	Belleville (B) Chatterton (B)	AA,l.t. AA,l.t.; LL	Weedy ditches	Rare Most numerous of the genus in l.t.

	1968	Belleville (M&J)	LL(52)	*Typha* marsh (G-9); mossy pool (H-8); willow scrub pools (J-8)	Coll. June 10-Aug. 27
CHAOBORIDAE					
Chaoborus (*Sayomia*) *albatus* Johnson	1952	Marmora (V)	AA		C.N.C. Coll. July 5-10, (3♂♂ and 2♀♀)
Chaoborus (*Chaoborus*) *americanus* (Johannson)	1958	Millbridge (J)	LL(29)	Semi-perm. pool beside Highway 62	Coll. July 18 at point 3.1 miles north of village. AA emerged in lab. July 25-Aug. 2
		Roslin (J)	LL(189), PP	Apparently a spring-fed pool 1.3 miles north of Chisholm's Mill	LL abundant. AA emerged in lab. July 29-Aug. 19 after collection on July 25. Several egg masses, each containing 50 to 250 eggs, were laid on water surface in a gelatinous support in the lab.
	1963-64	Roseneath (J)	LL, PP(63)	Natural farm pond fed by spring	Coll. Apr. 26-May 4. Located at the Coveney farm, 6 miles west of Warkwork. No culicines found
Chaoborus (*Chaoborus*) *flavicans* (Meigen)	1951	Belleville (J)	LL	Semi-perm. pool with *Typha* stand, beside C.N.R. line (L-7)	Coll. Nov. 30 Det. Dr. E. F. Cook (Cook, 1956)
	1952	Marmora (V)	LL		C.N.C. Reared adults emerged June 3-17
	1968	Belleville (M&J)	LL(22)	Willow scrub pools (J-8); *Typha* marsh (L-7) (I-8); mossy pools (H-8)	Coll. July 10
Chaoborus (*Schadonophasma*) *nyblaei* (Zetterstedt)	1951	Belleville (J)	LL	Large semi-perm. pool with *Typha* stand (L-7) beside C.N.R. line	Coll. Sept. 28 Det. Dr. E. F. Cook (Cook, 1956)

TABLE I. Mosquitoes collected in the Belleville district (*continued*)

Species	Year	Location and collector or author	Stage collected	Habitat	Remarks
	1958	Millbridge (J)	LL	Semi-perm. pool	Coll. Aug. 3
	1958-59	Roslin (J)	LL(5)	Spring-fed pool 1.3 miles north of Chisholm's Mill	Coll. May 19-July 25. Assoc. with LL of *Charborus americanus*
	1962	Cordova Mines (J)	LL(7), PP(6)	Deep perm. wood. pool	Coll. Sept. 7. Assoc. with LL of *Culex territans*
Mochlonyx cinctipes (Coquillett)	1952	Marmora (V)	LL(31)		Reared to adult stage: ♂, May 12; ♀♀, May 4-21. Det. Dr. J. R. Vockeroth
Mochlonyx velutinus (Ruthe)	1951	Chatterton (J)	LL	V. wood. pools Sine's swamp	LL coll. Apr. 6-May 24; PP, May 9-26. LL closely assoc. with *Aedes stimulans* and *A. trichurus* (James, 1957)
	1952	Marmora (V)	LL(11)		C.N.C. Det. Dr. J. R. Vockeroth
	1961	Cordova Mines (J)	LL(20)	Semi-perm. pool beside road, 0.2 mile south of Fish Hatchery	Coll. May 23-June 22
	1968	Belleville (M&J)	L	Typha Marsh (M-9)	Coll. Apr. 26

Discussion

Of the 45 species of Culicidae listed for Ontario by Steward and McWade (1961), 35 were recorded in this survey[1] and, in addition, 6 chaoborids. Belleville and its environs provided a total of 25 species of which all but 4 were collected in light traps.

Belleville lies in the Great Lakes-St. Lawrence deciduous forest region, but as Munroe (1956) points out, southern Ontario has been greatly modified by settlement and there is evidence, particularly from lepidopterous fauna (Riotte, 1966, personal communication) that Belleville forms part of an extension of the Carolinian zoogeographical province associated with beech-maple forest. The presence of the southern *Aedes thibaulti* appears explicable on these grounds.

Aedes dorsalis and *A. riparius,* however, are not typical woodland species and the former has probably been established for at least 30 years. There is botanical evidence that some parts of the district have affinities with the prairies (Dore, 1967, personal communication), and this together with the alkaline nature of many of the breeding sites may explain the presence of these two species.

Adults reared from collections of larvae and pupae helped to clarify some of the important breeding habitats in Belleville and vicinity. The mosquito breeding potential of the Herchimer Avenue marsh (J-8 and K-8) noted by Wishart in 1937 is still present since 13 species were collected there in 1968. A similar open marsh (G-8) yielded four species. Several small marshes, characterized by spring-fed pools and seepage pools with *Typha* stands were located at H-8, I-8, I-11, L-7, and M-9. These were habitats of eight culicids and two chaoborids. Four species of *Aedes* were collected in woodland pools and *Culex* larvae were found in marsh pools, ditches, or artificial containers.

Six culicids, mainly reported only since 1965 in Belleville, were collected at the following breeding sites: *Anopheles walkeri,* H-8; *Aedes abserratus,* I-15, J-8, M-9; *A. canadensis,* H-8, J-8, I-15, K-8, M-9; *A. cinereus,* I-11, J-8, K-8, M-9; *A. riparius,* G-9, H-8, L-9, M-9; and *Culex restuans,* J-8. The larvae of some of these occurred later than the snowmelt species.

Aedes stimulans and *A. excrucians* were by far the most abundant pest mosquitoes reared in 1968. Together with *Mansonia perturbans* they have probably undergone no great reduction over 30 years despite appreciable drainage and clearing, whereas *A. dorsalis* and *A. intrudens* have. The main breeding sites of *M. perturbans* appear to be the *Typha* marshes along the shore and inlets of the Bay of Quinte though much of the former marsh south of the city is now reclaimed land. *Aedes riparius, A. fitchii,* and *Culex territans* appeared moderately abundant. *A. vexans* was in seventh place, but larvae of *A. dorsalis, A. punctor,* and *A. implicatus* seemed very scarce.

Many former breeding sites in the city of Belleville have disappeared and others are now in the process of being filled in or drained. At the current rate of city and suburban development, it would appear that the present major larval habitats will eventually be eliminated. When this happens, pest mosquitoes may consist mainly of migrants from the surrounding countryside and Bay of Quinte.

Acknowledgment

The authors wish to thank Mr. C. F. Nicholls, Research Institute, Belleville, for help in preparing the illustrations.

[1]Adults reared by D. F. Riordan, Research Institute, Belleville, from a collection of larvae and pupae made at the field station near Chatterton on July 13, 1970 (while this paper was in galley proof) consisted mainly of *Aedes vexans,* but included a few *Aedes trivittatus* (Coq.). This raises from 35 to 36 the total Ontario species recorded in this survey.

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IV. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND SIXTH ANNUAL MEETING — ENTOMOLOGICAL SOCIETY OF ONTARIO

GUELPH, ONTARIO

AUGUST 25-29, 1969

The meetings were held in conjunction with the 19th Annual Meeting of the Entomological Society of Canada.

MEETING OF OUTGOING DIRECTORS

The 1968-69 Board of Directors met on August 25, 1969 in Room 316, Arts Building, University of Guelph. Those present were President J. M. Cameron, Vice-president H. W. Goble, past President H. R. Boyce, Directors S. E. Dixon, D. C. Herne, M. G. Maw, and Secretary-Treasurer D. H. Pengelly. Directors D. G. Harcourt and G. E. Shewell were absent.

The meeting was called to order by President Cameron at 7.40 p.m. His report outlined the major activities of the year as being concerned with the Library of the Society. This will be discussed later.

Minutes of the last Directors' Meeting were circulated to the membership in November, 1968. It was moved by S. E. Dixon, seconded by H. W. Goble that the minutes be approved. Carried.

The Directors approved the moving of the Society Library to new quarters in the McLaughlin Library and recommended that the present Library Committee of W. C. Allan, S. E. Dixon, W. E. Heming, and D. C. Herne be reappointed to draw up the Instrument of Agreement with the University, and to ensure safeguards concerning the identity and marking of the Society holdings. Much discussion followed on many aspects of the library, and it was recommended that one of the safeguards be on making it possible for the Society Library to be moved if necessary. A motion, presented by D. C. Herne that his committee, under the chairmanship of W. C. Allan, meet with Mr. McCrae, Librarian of the University of Guelph, to draw up the agreement on the status of the Society Library and present its report to the Board of Directors was seconded by M. G. Maw and was carried. It was suggested that this be circulated to the membership prior to the 1970 meetings.

The Directors reviewed the Financial Statements, the Editor's Report, the Report on the Common Names of Insects, and accepted these for inclusion in the agenda for the annual meeting.

It was pointed out that at the last Annual Meeting a motion was passed directing the Secretary-Treasurer to invest the Society funds in excess of a working minimum of $1,000. The Secretary-Treasurer reported that this was discussed at the last Director's meeting and because of the anticipated expenses of the combined meetings of the Ontario and the Canadian Societies, investing of funds was held in abeyance until after the obligations incurred at the meetings had been met.

A number of points was raised, and each point was referred to the incoming Board of Directors as they were concerned with committees to be appointed.

We were reminded again that Volume 100 of the Proceedings is going to press soon and we are urged to make this Centennial Volume a special one.

There being no further business, the meeting was adjourned.

ANNUAL MEETING

The 106th Annual Meeting of the Society was held in the Microbiology Building of the University of Guelph. Registration of members was conducted from 5 to 10 p.m. in Lambton Hall on August 25 and in the Microbiology Building from 9 a.m. onwards on August 26. The opening session began at 9.30 a.m. on August 26 under the chairmanship of President J. M. Cameron. Addresses of welcome were given by Dr. H. D. Branion, Assistant to the President, University of Guelph, and Dr. A. S. West, President of the Entomological Society of Canada. Fifty-four papers were presented during the four days of the meetings (some of these appear in the preceding sections of this volume).

Four papers, as follows, were presented during the morning and afternoon of August 26 in a symposium, "Pollution and the Entomologist", moderated by H. B. N. Hynes, Department of Biology, University of Waterloo:

HARRIS, C. R. (Soil Pesticide Section, Research Institute, Canada Department of Agriculture, London). Pollution and the soil organisms.

BRINKHURST, R. O. (University of Toronto). Pollution and freshwater organisms.

KEITH, J. A. (Canadian Wildlife Service, Ottawa). Pollution and the land vertebrates.

MURRAY, W. S. (Federal Committee on Pest Control, Washington, D.C.). Economics and pesticides.

Members of the Society attended a Social Evening, beginning at 8 p.m., at the Guelph Curling Club.

A session on Physiology and Development and on Ecology and Populations, under the chairmanship of A. J. Musgrave, was held on the morning of August 27, the following papers being presented:

SOHI, S. S. (Department of Fisheries and Forestry, Sault Ste. Marie). *In vitro* cultivation of hemocytes of *Malacosoma disstria* Huebner.

BHATNAGAR, R. D. S. (University of Guelph). Certain intrinsic factors influencing the post-embryonic development of the palpal organs of the wolf-spider, *Lycosa chaperi* S.

FOGAL, W. (Department of Fisheries and Forestry, Sault Ste. Marie). Cuticle structure and the role of bursicon in development.

DIXON, S. E. (University of Guelph). Some aspects of metabolism in honeybee larvae.

SHARMA, M. L., P. MARTELL, AND R. LAVIOLETTE (University of Sherbrooke). Biology and ecology of the insects of red pine and some reflections on their control.

SANDRESS J. N., AND J. A. MCMURTRY (University of British Columbia, Vancouver). Functional response of Phytoseiidae (Acari) to prey density.

LEONARD, D. E. (Connecticut Agricultural Experiment Station, New Haven). Intrinsic factors causing qualitative changes in populations of the gypsy moth.

DYCK, V. A. (Macdonald College). The microclimate in relation to the development and behavior of a population of *Melanoplus femurrubrum* (SeGeer) (Orthoptera: Acrididae). The climatic experience of grasshoppers in their natural habitat was estimated during the period of nymphal development. The period was calculated on the basis of sweep samples; results from a suction apparatus did not yield a more accurate growth rate. The dates of the beginning of successive instars were found by graphically plotting the peak numbers per instar. Nymphal development required approximately two months. Climatic factors measured included evaporation, relative humidity, and temperature. The evaporation rate increased with height above the soil surface. Relative humidity values were similar to those recorded in a Stevenson screen. Continuous measurements with unshaded thermistors revealed a temperature gradient in the habitat during the daytime, the temperature generally decreasing above the litter surface. The grasshoppers were found on the vegetation, primarily above the litter surface, during the day and the night. The highest temperatures measured in this region of the habitat between 16°C and 38°C were summed over the period of nymphal development in 1968, totalling about 9900 degree-hours C.

A session on Control and Control Aspects, under the chairmanship of F. L. McEwen, was held on the morning of August 27, the following papers being presented:

Scott, H. E. (North Carolina State University, Raleigh). Pesticides and people.

All vital processes are subject to control by the use of chemicals and chemical reactions. Chemicals influence the growth, development and behavior of all living organisms — plants and animals. The chemical makeup of man may be altered slightly, but in general the difference between a coward and a hero, and angry man and a peaceful one, or a fat man and a thin one is chemical. Agricultural chemicals contribute to the well-being of our people. We know a great deal about chemicals and their value to our economy. Therefore we can make suggestions about agricultural chemicals, especially pesticides, that will allow us to use them safely and properly, from the time they are located and purchased at the dealer's until they are properly stored, used, and the empty containers disposed of:

1. *Read the Label* — This is the first rule for intelligent use of pesticides. The USDA is responsible for seeing that all pesticides in interstate commerce are labelled properly and that cautions for the user's safety are stated. Once you purchase pesticides and remove them from the dealers premises they are your own responsibility. The label will tell you the uses for the chemical, namely, the crops on which it is registered, the rate per acre, and the precautions. Don't trust to memory — reread the label before each use.

2. *Store Pesticides Properly* — Store pesticides out of reach of your children and the neighbors' children as well. Store pesticides in their original containers with the labels intact since children are tempted to drink almost anything they find in a pop or milk bottle. And in case of an accident, since there are 60,000 different chemical labels in the registration files, your doctor must know what chemical caused the poisoning. Guessing on his part and the administration of the wrong drug could cause death, even if the pesticide had not. Be sure to store pesticides where they will not contaminate feeds of any kind or the water supply.

3. *Application of Pesticides* — Always mix pesticides in a well ventilated area, preferably out of doors. Keep children and pets out of the area while applying pesticides, even if the chemicals are regarded as non-poisonous. Apply the correct amount of pesticide — don't guess. It is easy to make a 300% mistake, for example, to use a tablespoonful instead of a teaspoonful per gallon. Treat on a calm day. Calm weather keeps you from coming in contact with the spray or dust, and it avoids drift problems in your yard or even the neighbors'. Some chemicals are phytotoxic, so unless you know otherwise from firsthand experience, apply only to those plants listed on the label.

4. *Disposal of Waste Pesticides and Pesticide Containers* — When any glass or metal container is empty, rinse with water and either use the water in the spray operation or dig a hole in the ground, pour in the water and cover it up. Small glass and metal containers handled as above may be broken, punctured or otherwise made unusable and disposed of in the garbage. Large containers should be rinsed and returned to the dealer from which obtained, or sold to a cooperage firm. Cartons, bags, etc, should be burned. Be sure, however, to stay out of the smoke. Useless waste chemicals should be buried or disposed of in such a manner as to avoid injury to people or livestock and the contamination of any food or water supply.

Parent, B. (Research Station, Canada Department of Agriculture, St. Jean, Quebec). Chemical control of the oystershell scale, *Lepidosaphes ulmi* (L.), on apple in Quebec.

Musgrave, A. J. (University of Guelph). A potential new systemic approach to control of blood-sucking arthropods using *Rhodnius prolixus* feeding through a membrane.

Following a suggestion of Musgrave in 1964, some preliminary trials were made on the effect of antibiotic-treated, defibrinated mammal blood fed through a membrane to *Rhodnius prolixus*. Complete or high mortality resulted. *In vivo* experiments have given promising results. More detailed account in Can. Entomol. 101: (757-759)

Howitt, A. J. (Michigan State University, East Lansing). The use of controlled porosity using sintered metal in low volume and ultra low volume spraying.

McClanahan, R. J. (Research Station, Canada Department of Agriculture, Harrow). Biological and chemical controls can be integrated for greenhouse pest control.

Nigam, P. C. (Chemical Control Research Institute, Ottawa).Wide-spectrum toxicity of Zectran against forest insect pests.

In an attempt to replace DDT and other chlorinated hydrocarbon insecticides, Zectran has been tested along with 60 other compounds, under laboratory conditions against 10 species of forest insect pests for contact, residual, and systemic toxicity since 1965. The relative contact toxicity is compared on he basis of LD_{50} values at 48 hours after treatment except where otherwise noted below. The toxicity of Zectran is

presented in relation to DDT or Sumithion as they have been used in field operations against most of the pests, with the exception of ambrosia beetle, *Trypodendron lineatum* (Oliv.), where BHC is used.

Zectran was 48 times more toxic than DDT to fifth instar spruce budworm, *Choristoneura fumiferana* (Clem.) its toxicity to sixth instar jack-pine budworm, *Choristoneura pinus* Free., was 6 times more than Sumithion. It was 1.7, 3 and 5 times more toxic than Sumithion against third instar larvae of eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), western hemlock looper, *L. f. lugubrosa* Hulst., and green-striped forest looper, *Melanolophia imitata* Wlk. respectively, when compared at 100% mortality at 72 hours after treatment. Zectran was 38, 56, and 238 times more toxic than DDT against fourth instar larvae of larch sawfly, *Pristiphora erichsonii* (Htg.), Swaine jack-pine sawfly, *N. swainei* Midd., and black-headed jack-pine sawfly, *Neodiprion pratti banksianae* Roh., respectively. It was 5 times more toxic than Sumithion to European pine sawfly, *N. sertifer* (Geoff.). The toxicity of Zectran to ambrosia beetle adults was 8 times more than BHC.

Zectran at the rate of 8 oz active/acre was translocated to unsprayed foliage in toxic amounts, from sprayed portions, when small potted jack-pine plants were sprayed in the laboratory. Sumithion and phosphamidon were translocated at 32 oz/acre to show activity. However, neither of these compounds appeared to act as a true systemic at operationally successful rates of 2 to 4 oz active/acre. The same was true for other systemic insecticides tested.

Residual toxicity of Zectran lasted up to 30 days against sawflies under controlled laboratory conditions when applied at the rate of 1.6 oz active/acre on potted jack pine trees. When sprayed potted spruce plants were held under natural weathering conditions, toxicity to spruce budworm lasted from 5 to 10 days depending on various factors. The use of Zectran in control operations will depend upon the results of field trials and commercial availability of the compound.

Eidt, D. C. and C. H. A. Little (Forestry Research Laboratory, Fredericton, New Brunswick). Insect control through induced host-insect asynchrony — a progress report.

Batth, S. S., and Mrs. J. M. Stalker (Pesticide Testing Laboratory, Canada Department of Agriculture, Ottawa). A survey of Canadian populations of the housefly for resistance to insecticides. The first-generation offspring of samples of Canadian housefly populations were tested for resistance to various insecticidal chemicals, using a topical application method. All of the collections showed a high level of resistance to DDT, γ BHC, and malathion; most also showed moderate resistance to ronnel. There was no evidence of any substantial degree of resistance to dichlorvos, though some collections were somewhat more tolerant than others.

A luncheon, including presentation of the Gold Medal of the Entomological Society of Canada, was held at 12 p.m. in the cafeteria of the Physical Education Building.

On Wednesday afternoon, August 27, the competition for the President's Prize of the Entomological Society of Ontario was held, the following papers being presented:

Kuo, J. S. (Carleton University, Ottawa). Termination of the hypopal stage of *Caloglyphus mycophagus* (Megnin) (Acarina: Acaridae).

Caspary, V. G., and A. E. R. Downe (Queen's University, Kingston). Preliminary studies of the swarming and mating of *Chironomus* sp. in the laboratory.

Swarming was found to be essential for mating and oviposition in *Chironomus riparius*. Partial suppression of swarming by mechanically limiting the cage volume for swarming resulted in fewer matings and ovipositions than occurred under optimum laboratory conditions. When the available space became too limiting, swarming did not occur and mating and oviposition were blocked indefinitely.

In these experiments sperm transfer was detected by labelling sperm with adenine -8-C^{14}. Results showed that a male mated a maximum of two times in its life span of 3 to 4 days.

Observations showed that overlapping periods of male and female activity maximized the number of matings as this ensured that fully sexually aroused adults met.

Light intensity, photoperiod, sound and swarm marker qualities were all manipulated and found to have an effect upon swarm formation. Findings concerning the possible involvement of pheromones were inconclusive. A provisional behavioral model has

been developed in which the sequential behavioral units of the males and females (male antennal stroking, walking, flying, swarm formation, and copulation) are triggered and/or influenced by the above experimental variables. Verification of details of this model requires further research.

Downer, R. G. H. (University of Western Ontario, London). Hormonal control of lipid concentrations in the fat body and hemolymph.

Shrivastava, H. (York University, Toronto).. Hemoglobins of *Chironomus riparius.*

Thomson, A. J. (McMaster University, Hamilton). The biology of *Pollenia rudis* (Fab.), the cluster fly (Diptera: Calliphoridae).

The importance of high humidity and contact with a moist substrate for the hatching and survival of the cluster fly larvae was indicated. It was shown that the larvae move randomly through the soil until they contact an earthworm, whereupon the larvae are induced to penetrate by a substance present in fresh worm slime. The slime from several species of earthworms is capable of inducing penetration behavior. Oviposition by the adult flies is influenced by temperature and humidity and by some soil factors, especially soil moisture and compactness. Peak oviposition occurred in soil of a moisture content preferred by *Allolobophora caliginosa,* a reported host of *P. rudis.* Other reported hosts are *Eisenia rosea, Allolobophora chlorotica,* and *Lumbricus terrestris.* The study of the ecology of the host earthworms was emphasized as a prerequisite for further investigations of the host-parasitic relationships.

Steel, C. G. H. (Queen's University, Kingston). Stimulus response dynamics in the neuroendocrine system of *Rhodnius.*

A session on Physiology and Development, under the chairmanship of S. E. Dixon, was held on the morning of August 28, the following papers being presented:

Bhatnagar, R. D. S., and A. J. Musgrave (University of Guelph). Some comments on the relationship between *Sitophilus* weevils and their mycetomal plasmids as revealed by histochemical tests.

The large, elongate rod-shaped plasmids containing DNA were found to be Gram variable and non-acid fast. There was evidence of reproduction by endospores and binary fission. Imaginal midgut caecae harboring plasmids seemed to be richer in mucopolysaccharides and glycogen than those apparently lacking plasmids.

Owusu-Manu, E. and R. K. Stewart (Macdonald College, Quebec). Studies on the induction of diapause in *Hylemya brassicae* (Bouche) (Diptera: Anthomyiidae).

Gooding, R. H. (University of Alberta). Studies on proteinases from blood-sucking insects.

Yang, Y. J., and D. M. Davies (McMaster University, Hamilton). The changing pattern of digestive enzymes during development of blood-sucking flies.

Smith, J. J. B., and W. G. Friend (University of Toronto). Feeding in *Rhodnius prolixus.*

Charlton, Mrs. C., and Susan B. McIver (University of Toronto). Studies on the sense organs on the palps of selected culicine mosquitoes.

Pratt, G. E., and K. G. Davey (Macdonald College, Quebec). Gross effects of allatectomy on *Rhodnius prolixus.*

The corpus allatum was removed from mated adult female *Rhodnius,* and the effects on the ovary examined. Measurement of the length of the three largest oocytes in each ovariole on each of the first 6 days after feeding shows that in both normal and allatectomised animals the growth of adjacent oocytes is markedly coordinated. When the oocytes reach 300-400μ in length, vitellogenesis begins; this is accompanied by the opening up of spaces between follicle cells as revealed by the penetration of Evans blue into these spaces. Allatectomy increases the number of oocytes in this critical transitional range of 300-400μ and increases the time required to complete vitellogenesis once it has begun. Activated nurse cells are those which contain large aggregates of material which stain with acridine orange. This material, which is thought to be RNP, passes down the trophic cords. Allatectomy decreases the number of mitoses in the primordium of the tropharium, but slightly increases the number of activated nurse cells which arise from the primordium. The delayed entry into, and slow rate of vitellogenesis account for the overall inhibition of egg production after allatectomy. Principal yolk protein of apparent M.W. 320,000 containing 3% Hexose by the anthrone method, can be isolated by gel-filtration chromatography on columns of

"Sephadex G-200". Examination by five different electro-kinetic techniques indicates two species of different electrical charge which are immunologically identical or highly cross-reacting. Mono-specific antisera can be obtained. Quantitative radial immunodiffusion assay of haemolymph taken after feeding shows that the mean concentration of yolk protein in allatectomised animals is half that in normals.

PRATT, G. E., AND K. G. DAVEY (Macdonald College, Quebec). The corpus allatum and oogenesis in mated and virgin females of *Rhodnius prolixus*.

In the absence of a mating stimulus, the adult female *Rhodnius* makes fewer eggs and lays them later and more slowly. The inhibition of egg production has been examined and compared with that found after allatectomy (previous abstract). The inhibition is time-dependent and operates exclusively upon the second wave of eggs after the feed. These eggs enter vitellogenesis but become arrested and lie dormant; dye will no longer penetrate the follicle epithelium. A simultaneous accumulation of oocytes in the transitional size range (300-400μ) suggests a physiological allatectomy. However, quantitative hormone replacement with topically applied all-trans farnesyl methyl ether suggest that this may not be the case. A dose of 0.5 microlitres per animal is required to activate the second wave of oocytes in a virgin, while a dose of 0.01 microlitres activates the first wave in decapitated mated females and a dose of 0.005 microlitres will prevent metamorphosis. The enhancement of egg production in virgins by the analogue requires the median neurosecretory cells of the brain and is accompanied by rapid oviposition.

Immuno-assay of the yolk protein concentration of the haemolymph shows the normal level to persist for longer in virgins than in mateds. The ultimate decline occurs long after the onset of ovarian inhibition and accompanies the onset of starvation in both cases. It is concluded that virgins suffer not an insufficiency of allatum hormone but rather an active inhibition which is associated with a failure to release neurosecretion and to oviposit rapidly. The importance of quantitation in investigation of endoctrine balance is emphasized.

PRATT, G. E. AND K. G. DAVEY (Macdonald College, Quebec). Starvation and oogenesis in *Rhodnius prolixus*.

Prolonged starvation causes resorption of larger oocytes, a decrease in hemolymph exsanguination volume, and in the hemolymph concentration of yolk protein determined immunologically. When refed, the terminal oocytes average 150 microns in length, and grow slowly to 350 microns by day 4. There is then no delay before entering vitellogenesis on day 5. Hemolymph yolk protein rises to normal by day 3. During inhibition the tropharium gives a very weak reaction for protein with Ponceau S and there are no activated nurse cells. The symptoms of starvation do not resemble those of allatectomy in the fed animals; it may be unnecessary to involve endocrines in the starvation syndrome. The concentration of yolk protein in the hemolymph does not regulate vitellogenesis in intact *Rhodnius*. While circulating allatum hormone is required for maximum ovarian growth, its postulated role as a unique physiological controller of oogenesis can bear review.

A session on Populations and Ecology, under the chairmanship of W. E. Heming, was held on the morning of August 28, the following papers being presented:

SOHI, S. S., C. R. SULLIVAN, AND C. L. BODLEY (Department of Fisheries and Forestry, Sault Ste. Marie). A simple controlled rate freezing device.

Mammalian cell cultures are routinely preserved in liquid nitrogen refrigerators at —196°C to prevent chromosomal mutation, microbial contamination, and accidental loss of cultures. These cells generally require a slow controlled rate of cooling from room temperature to about —30°C to prevent injury during freezing. This is usually accomplished by using quite sophisticated and expensive equipment.

A simple and inexpensive device was developed for freezing insect cell cultures. This equipment provides a slow rate of cooling from room temperature to about —40°C. Canes with ampules are placed in the cooling device, cooled to —40°C at a predetermined rate and transferred to liquid nitrogen refrigeration immediately. No further handling of individual ampules is necessary.

TRAYNIER, R. M. M. (British Columbia Research Council). Habituation of the response to sex pheromone in the Mediterranean flour moth.

CHENG, H. H. (Research Station, Canada Department of Agriculture, Delhi). Assessment of tobacco losses caused by the dark-sided cutworm, *Euxoa messaria* (Harris) (Lepidoptera: Noctuidae).

Pritchard, G. (University of Calgary). Estimation of natality in a fruit-infesting insect.

Extraction of eggs of the Queensland fruit fly *(Dacus tryoni)* from fruit was aided by first identifying the oviposition sites with a water-soluble dye, and secondly digesting the fruit tissues around the oviposition site with a mixture of enzymes consisting of equal parts of 1% pectinase and 1% cellulase. Because of fruit-fall, hatching of eggs within a week, and persistence of the fruit on trees for more than one week, estimation of the number of eggs laid per week over the long period of oviposition required a knowledge of the numbers of hatched and unhatched eggs present on one occasion each week, the rate of fruit-fall, the proportion of infertile eggs, and the developmental time of eggs. The latter was estimated from a curve relating speed of development in the laboratory to constant temperature, and hourly thermocouple records from a site beneath the skin of fruit in the field. An outstanding problem is the variable mortality rate of eggs in different varieties of fruit. It was hypothesized that this was related to the crowding of eggs in oviposition sites, which was in turn related to the ease with which the skin of fruits of different varieties was punctured.

McCambridge, W. F. (Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado). Spermatozoa in unemerged female mountain pine beetle, *Dendroctonus ponderosae*, brood.

Barras, S. J. (Southern Forest Experiment Station, Pineville, Louisiana). The mycangium of *Dendroctonus adjunctus* and its associated fungi.

Chapman, J. A. (Forestry Research Laboratory, Victoria, British Columbia). Studies on scolytid beetle eyes.

The celloidin film replica method was used to secure accurate counts of ommatidia number in five scolytid species: *Dendroctonus pseudotsugae* Hopk., *D. obesus* (Mann.), *D. valens*, Lec., *Dryocoetes autographus* (Ratz), *Hylastes nigrinus* (Mann.), *Trypodendron lineatum* (Oliv.). Average number per eye ranged from 372 to 138 in these species. These insects have simpler eyes than other beetles for which counts are reported. Presumably, this reflects a lesser dependence by scolytids on vision. Comparisons show no significant difference in number between geographic races of one species, or between the sexes of two species, but an interesting variation between right eye and left eyes of the same beetles.

Chutter, F. M. (Research Institute, Belleville). The potential fecundity of newly emerged females of *Cnephia dacotensis* (Dyar and Shannon) (Diptera: Simuliidae).

Mathieu, J. M., and R. A. Mathieu (Institute of Technology, Monterrey, Mexico). Life cycle and behavior of *Chromacris colorata* (Romaleinae: Acrididae).

On the afternoon of August 28, the competition for the President's Prize was continued, the following papers being presented:

Hebert, P. D. N. (Queen's University, Hamilton). Population genetics of the forest tent caterpillar, *Malacosoma disstria.*

Chen, Amy Whei-Mei (McMaster University, Hamilton). Changes in the simuliid ovary during oogenesis (Diptera).

Blaine, W. D. (University of Guelph). Hormonal control of spermatogenesis in the cockroach, *Periplaneta americana.*

The Annual Meeting of the Entomological Society of Canada was held on the afternoon of August 28, beginnning at 2.45 p.m. In the evening, starting at 6.30 p.m., a cocktail hour and banquet were held in the cafeteria of the Physical Education Building.

A session on Nutrition and Populations, under the chairmanship of W. G. Friend, was held on the morning of August 29, the following papers being presented:

McGinnis, A. J., S. R. Loschavio, and D. R. Metcalfe (Research Station, Canada Department of Agriculture, Winnipeg). Nutritive value of cereal varieties assessed with the confused flour beetle.

Ekka, I., and F. O. Morrison (Macdonald College, Quebec). Culture of the two-spotted spider mite, *Tetranychus urticae* (Koch), on chemically defined diets.

Wilson, G. G. (Forestry Research, Sault Ste. Marie) and A. J. Thorsteinson (University of Manitoba). The effects of food plants and food-plant constituents on growth and

mortality of the migratory grasshopper, *Melanoplus sanguinipes* inoculated with *Nosema locustae* Canning.

The effects of various dehydrated food plants and secondary plant chemicals on a grasshopper were tested. Of the various plants tested only blue lettuce (*Lactuca pulchella*), wild mustard (*Brassica kaber*), orchard grass (*Dactylis glomerata*) and lamb's quarters (*Chenopodium album*) were discussed. The results of the study indicate that pharmacological stress may play a major role in the mortality of insects infected with a pathogen. The poor plant diets and dandelion (*Taraxacum officinale*) meal containing the secondary plant chemicals, digitonin and coumarin acting as stress factors, significantly decreased the time to mortality of the infected insects.

SINGH, P. (Research Institute, Belleville). Effects of antimicrobial agents on dipterous parasites, *Agria affinis,* reared on chemically defined diets.

Antimicrobial agents are often added to the synthetic diets of insects to prevent microbial contamination, but their effects on insects are not well-known.

Twenty-one antimicrobial agents (Aerosporin, Albamycin, Aureomycin, Bcitracin, Bradosol, Chloromycetin, Erythrocin, Ethanol, Formalin, Gantrisin, Kantrex, Methyl-p-hydroxy benzoate, Mycifradin sulfate, Penicillin G Potassium, Potassium sorbate, Sodium benzoate, Streptomycin sulphate, Terramycin, Tetracin, and Vancocin) were tested by feeding them to larvae of *Agria affinis* auct. nec Fallén (Diptera: Sarcophagidae) in a chemically defined diet under aseptic conditions. This showed that a given agent can be toxic, arrest growth, and also reduce the size of larvae, and consequently the pupae and adults. All these effects depend upon (1) the specific antimicrobial agent; (2) its concentration; and (3) the dietary nutrient level.

Based on these effects on the larvae, the "safe levels" of these 21 agents were determined. The safe level was defined as that level of an antimicrobial at which no detrimental effects on the insect are evident. Results of these findings and prospects of future work were presented.

A session on Evolution and Morphology, under the chairmanship of W. C. Allan, was held on the morning of August 29, the following papers being presented:

HEMING, B. S. (University of Alberta). Bladder feet (protrusible arolia) in Thysanoptera.

Thysanoptera are distinguished by the unusual nature of their pretarsi. The components of the pretarsus (arolium, ungues, unguitractor plate and its tendon, pretarsal depressor muscle and unguifer) are homologous with those of other insects, but changes in their relative size and shape have resulted in pronounced shifts in the way they function. Chief among these are the enlargement of the median lobe or arolium into a protrusible bladder; the reduction of the pretarsal claws or ungues into flat, ensheathing plates; and the development of a "tibial" gland whose elaboration enters the lumen of the bladder. The contraction of the pretarsal depressor muscle, instead of flexing the ungues, causes them to rotate outward on the unguifer thus allowing blood pressure originating in abdominal contraction to evert the bladder.

The mechanism is basically the same in the adults of the species in all five families of the order. In the two larval stages the mechanism is also similar but there is no "tibial gland", the arolium is relatively small, and the ungues are more claw-like. In the quiescent instars of the life cycle this pretarsal mechanism ceases to operate due to the histogenesis of the adult structures.

GUPPY, J. C. (Research Institute, Ottawa), AND C. D. F. MILLER (Research Station, Harrow). Identification of cocoons and last-instar larval structures of parasitoids reared from *Pseudaletia unipuncta* in eastern Ontario.

CUTTEN, F. E. A., AND D. K. M. KEVAN (Macdonald College, Quebec). The larvae of *Palaeodipteron walkeri* Ide. (Diptera: Nymphomyiidae) in an unpolluted Quebec stream.

ATWOOD, C. E., AND G. KNERER (University of Toronto). Some evolutionary trends in the genus *Neodiprion* in eastern North America.

The Annual Meeting of the Entomological Society of Ontario was held at 10.20 a.m. in the Microbiology Building on August 29, and on the same day at 1.30 p.m. the Directors of the Entomological Society of Canada met in the Arts Building of Wellington College, and the Directors of the Entomological Society of Ontario met also in the Arts Building.

ANNUAL BUSINESS MEETING

The Annual Business Meeting was held at 10.25 a.m. on August 29 in the Microbiology Building.

The meeting was called to order by President Cameron and a minute of silence followed to express our regrets on the passing of Dr. E. M. Walker.

The Secretary-Treasurer reported that the minutes of the last meeting had been circulated to the members. It was moved by H. R. Boyce, seconded by C. R. Sullivan, that the minutes be accepted. Carried.

President Cameron reported that the resolution passed last year on improving the quality of visual aids at our meetings has been acted upon. A list of criteria designed to provide clearer, more meaningful visual aids was prepared by President Cameron and circulated to all members and contributors. This will continue to be used by the Society. Comments from the members will be appreciated.

Financial Statement for year ending December 31, 1968: The "Cheque Returned" was questioned and an explanation was given by the Secretary-Treasurer. These are not lost accounts but cheques that cannot be handled by the banks in the normal manner. It was moved by C. D. F. Miller, seconded by A. H. Rose that the Financial Statement be accepted. Carried. (See Appendix I. Proceedings of the Society, Volume 99 (1968), page 86.)

The Interim Financial Statement was presented and members were informed that the Investment Certificates now bear interest at 9¼% over a 5-year period. The acceptance of the report was moved by W. C. Allan, seconded by D. C. Herne. Carried. (Appendix I)

The following Directors were elected for the year 1969-70:

S. E. Dixon, Guelph
R. L. Edwards, Peterborough
M. G. Maw, Belleville
J. H. H. Phillips, Vineland
P. J. Pointing, Toronto
G. E. Shewell, Ottawa
C. R. Sullivan, Sault Ste. Marie

Of the persons nominated for Fellowship in the Society in 1968, three were approved by the Directors. These names were submitted to the Membership and received their approval.

Elected as Fellows of the Entomological Society of Ontario are:

A. W. A. Brown
E. M. DuPorte
R. Glen

REPORT OF THE EDITOR

Volume 99 of the Proceedings has been printed, and includes five reviews of infestations of insects and other pests, seven invitation papers, five submitted papers and the Proceedings of the 105th Annual Meeting held at Sault Ste. Marie, October 2 to 4, 1968.

Members of the Society and other entomologists are encouraged to submit papers on all branches of entomology for Volume 100, in particular reviews of infestations and studies of insects in Ontario. Arrangements have been made to have abstracts taken directly from the Proceedings for Biological Abstracts. Authors are therefore requested to insert an "Abstract" of the article in the manuscript of an article between the name and address of the author and the main body of the article. Please prepare papers according to the guide on the inside back cover of Volume 98 or 99 and submit them by January 15, 1970.

W. W. Judd, Editor

Moved by J. Teskey, seconded by C. E. Atwood that the report be accepted.

Discussion: It was noted by D. C. Herne that the Proceedings does not carry obituaries. In respect to cost, the present system is the same as that of a full page obituary. The question was referred to the incoming Directors.

D. M. Davies asked that all persons contributing papers to the Annual Meeting be asked to submit an abstract for inclusion whether the paper is printed in the Proceedings or not. It was suggested that this procedure begin with this meeting. An abstract is to be called for with the Call for Papers.

Report to 1969 General Meeting, Entomological Society of Ontario from ESO representative to the ESC Committee on Common Names of Insects.

During the past year the Committee continued to investigate means by which an agreeable basis could be worked out for the ESC to have a voice as a Society with the

Entomological Society of America in adjudicating upon common names for this continent. A proposal to this end was submitted to the ESA Committee, but was rejected, although that Committee did agree that "broader North American representation was desirable". The ESA Committee did propose to regulate its membership to include two Canadians, and one Mexican or a United States citizen with close Mexican ties. The recommendation was passed to their nominating committee, which did nominate two Canadians, but only one was elected. The composition of the ESA Committee has therefore not changed with respect to Canadian representation. The ESC Committee still regards the issue as unsettled to its satisfaction.

Efforts continue to standardize common names for those insects in Canada which clearly warrant them. The Canada Department of Agriculture has published a *List of insect and related pests of major economic importance or special interest.* Forty-five of the species listed lack common names. Efforts are under way to have these names documented and approved.

It is proposed to arrange for distribution of the ESA list of approved common names to the members of the ESC.

Glenn B. Wiggins

Acceptance was moved by D. M. Davies, seconded by J. F. McAlpine, and carried.

D. C. Eidt, Chairman of the Canadian Committee said the matter of representation on the Entomological Society of America's committee was closed but would be re-opened in 1972. Motion carried.

LIBRARIAN'S REPORT

For some years it has been very evident that our library needed changes.

Space was adequate but not practical; it was dusty, inaccessible, difficult to staff and subject to very undesirable temperatures. A move to new quarters was an obvious necessity.

As early as 1966 it was reported to the Society that the space which our Library occupied was at a premium and was required by the academic part of the Department of Zoology.

Examination of all possible locations indicated McLaughlin Library to be the most satisfactory, and that the integration of our holdings into the Prime Section of the McLaughlin Library would be the most useful method of operation.

At Kingston in 1967 the membership gave approval for such a move and such a plan, and this was further endorsed at the meeting at Sault Ste. Marie in 1968. The move has been completed and our holdings are now cataloged in the Central Library System Policy.

This does not mean that we have given away the Library, but merely that it has changed its home, and by so doing has enhanced its value. McLaughlin Library is prepared to complete series where required, to bind many of our old journals, to place all titles on microfilm catalogs, to make the holdings available seven days a week and for at least ten hours per day, to provide special rooms for books considered to be in the rare category (of which we have quite a few) and to provide many other services which heretofore were not possible.

Journals will be received and stamped with a special *Entomological Society Library* stamp. Library privileges are extended to all members of both Societies.

It is proposed that a meeting of the Library Exchange Committee be arranged for the near future so that we can examine and change, if thought necessary, our present exchanges and exchange holding.

A write-up concerning our Library in the News Bulletin of the University, Vol. 14, No. 36, dated August 28, 1969, is now available and I am sure that the members will find it very enlightening.

W. C. Allan, Chairman

Moved by W. C. Allan that the report be accepted, seconded by C. R. Sullivan. Carried.

A. W. Baker questioned the wording of the Book Plate, and explained that in the original agreement the Library was to continue as that of the Entomological Society of Ontario and the Entomological Society of Canada, and thus the volumes should be designated as the 'Entomological Society Library'.

Much discussion on the status of the Library ensued and the negotiation of an agreement was again referred to the Library Committee. It was stated emphatically that the Library was not being given to the University. Carried.

NEW BUSINESS

D. C. Herne, on behalf of the Vineland Station, invited the Society to meet there in 1970. Moved by C. D. F. Miller that the invitation be accepted, seconded by S. E. Dixon. Carried.

The question of increased dues in the Canadian Society, and its possible effect on the Ontario Society was raised by D. C. Herne, but was referred to the Directors.

The absence of commercial representation at our meetings has been of concern to many of the entomologists, and it was suggested that efforts be made to make the program of more interest to them.

R. L. Edwards raised the question of employment in relation to the number of graduate students in entomology, as there are few employment opportunities in Canada. Should we, as a Society, be concerned about the supply and demand?

B. S. Heming commented that if we do not raise the question of employment the students will.

S. E. Dixon suggested that there be a national body established to determine the future needs of entomologists, and that such a body would be more effective that the present system.

P. S. Corbett discussed planning, actions, and recommendations that should be considered.

The matter was referred to the Directors.

The Secretary was instructed to write to members of the Society who, through illness, were unable to be present this year.

REPORT OF RESOLUTIONS COMMITTEE

1. WHEREAS the members of the Society have enjoyed the accommodations provided by the University of Guelph, for holding of this, the 106th Annual Meeting BE IT RESOLVED that we extend to the University our sincere thanks for their part in making these meetings a success.
2. WHEREAS the program of the meeting has been excellent in both the appropriateness of the general theme "Pollution and the Entomologist" and in the quality of the entire program BE IT RESOLVED that we extend to the members of the local committee, under the chairmanship of Dr. P. E. Morrison, our sincere thanks for their efforts.
3. WHEREAS the invited speakers for the symposium on "Pollution and the Entomologist" gave us much thought-provoking and timely information BE IT RESOLVED that we extend our thanks to the Moderator Dr. H. B. N. Hynes, and to the speakers Dr. C. R. Harris, Dr. R. O. Brinkhurst, Mr. J. A Keith, and Dr. W. S. Murray for their contribution to the program.
4. WHEREAS the competition for the President's Prize is a valuable means of stimulating the interest of students in the field of entomology BE IT RESOLVED that we extend to Dr. W. F. Baldwin, Dr. C. R. Sullivan, and Mr. D. G. Peterson our thanks for their work in the difficult task in judging the entries, and that through the Secretary we express to Dr. W. F. Fletcher our regret that he was unable to be with us to continue the judging for which he has been responsible since the inception of the competition.

Appointment of Auditors: Moved by J. MacB. Cameron, seconded by E. C. Becker that Saunders and Wright be reappointed as auditors. Carried.

The meeting adjourned at 12.15 p.m.

MEETING OF INCOMING DIRECTORS

The meeting of incoming Directors for 1969-1970 was held in the Arts Building, at 1.30 p.m. Directors present were J. M. Cameron, S. E. Dixon, R. L. Edwards, M. G. Maw, J. H. H. Phillips, P. J. Pointing and C. R. Sullivan. G. E. Shewell was absent. D. H. Pengelly, Secretary-Treasurer, was present.

The meeting was called to order by J. MacB. Cameron and nominations for President were opened. C. R. Sullivan nominated S. E. Dixon. There being no further nominations, President Dixon took the chair. M. G. Maw nominated R. L. Edwards for Vice-President. There were no further nominations.

The minutes of the last Directors' Meeting were read and approved on a motion by J. MacB. Cameron, seconded by C. R. Sullivan.

Business Arising from the Minutes: Points of concern from the Directors' Meeting will be discussed under the various committees and appointments.

Library Committee: The previous Directors recommended that this committee (W. C. Allan, S. E. Dixon, W. E. Heming, D. C. Herne) be reappointed. It was moved by J. H. H. Phillips seconded by P. J. Pointing that the recommendation be accepted. The Directors were referred to the motion by D. C. Herne and seconded by M. G. Maw passed at the previous meeting of Directors. Motion carried.

W. C. Allan was asked to continue as the Ontario Representative on the Library Committee with the Entomological Society of Canada Representative. It was moved by P. J. Pointing, seconded by J. H. H. Phillips that the Library Committee be funded if needed, up to a maximum of $200. Carried.

Appointment of Editor and Editorial Committee: Moved by C. R. Sullivan, seconded by R. L. Edwards that Dr. W. W. Judd be asked to continue as Editor. Carried. The Directors appointed Dr. G. McLeod and Dr. J. E. Steele as members of the Editorial Committee.

The Directors recommended that the Nominal Roll of the Fellows of the Entomological Society of Ontario be carried on the inside front cover of the Proceedings. It was also recommended that obituaries of members of our Society be carried in full.

Appointment of Secretary-Treasurer: It was moved by M. G. Maw and seconded by R. L. Edwards that D. H. Pengelly be reappointed. Carried.

Director-at-Large in the Entomological Society of Canada: It was moved by R. L. Edwards, seconded by P. J. Pointing that C. R. Sullivan be appointed. The term to be for 1 to 3 years, in accordance with the Constitution of the Entomological Society of Canada. Carried.

H. R. Boyce, because of retirement, was unable to complete his term of office. Thanks are extended to him for his work as President.

Appointment of Scrutineers: It was moved by D. C. Herne, seconded by J. MacB. Cameron that W. C. Allan and F. L. McEwen be appointed. Carried.

Appointment of Nominating Committee: It was moved by M. G. Maw, seconded by C. R. Sullivan that J. H. H. Phillips be chairman of the committee that included J. MacB. Cameron, Past President, and D. H. Pengelly, Secretary-Treasurer. Carried.

Appointment of Representative on the Committee on the Electing of Fellows of the Entomological Society of Canada: It was moved by D. C. Herne, seconded by M. G. Maw that the President of the Ontario Society be empowered to act in accordance with the constitution of the Entomological Society of Canada. Carried.

New Business: The question, referred to the Directors by the annual meeting, on supply and demand of entomologists was raised. After some discussion it was moved by C. R. Sullivan, seconded by D. C. Herne, that R. L. Edwards (chairman) and P. S. Corbet be appointed as a working Committee on Student Employment. This Committee has the power to add further members. Carried.

A Committee on the President's Prize, to consist of M. G. Maw, S. E. Dixon and D. H. Pengelly, was formed on a motion by J. MacB. Cameron, seconded by D. C. Herne.

All members are urged to give full consideration to the future in the training of entomologists and to the social problems inherent in insect control. Bring your ideas to the meetings in Vineland.

APPENDIX I

FINANCIAL STATEMENT FOR YEAR ENDING DECEMBER 31, 1969

RECEIPTS		DISBURSEMENTS	
Dues Received	$4,080.10	Dues to Ottawa	3,281.00
Exchange Included	19.75	Exch. paid on cheques	38.35
Sale of Reprints	1,707.90	Library	200.00
Sale of Proceedings	77.72	Stationery	302.14
Sale of Insect Cabinets	381.00	Printing	1,043.41
Bank Interest	143.19	Postage	485.22
Bond Interest	18.00	Cheque Returned	10.00
Premium U.S. Funds	50.66	Refund on Proceedings	1.00
Grant from Ont. Govt.	300.00	Honorarium to Sec-Treas	150.00
Bank error on deposits	20.00	Sec Assistant	25.00
Annual Meeting		Annual Meeting	
Receipts	1,710.00	Printing	210.74
Cash	300.00	Cash	300.00
Grant ESC	500.00	Social	536.48
Expenses paid by ESC	495.80	Transportation	111.00
Refund from Social	327.00	Luncheon and Banquet	966.46
	10,131.12	Expenses P. E. Morrison	80.00
Bank Balance Jan. 1/69	2,697.19	Room (Panellist)	8.40
Bonds	400.00	Coffee	123.47
Investment Certificate	670.81	Panellists' Expenses	262.00
	13,899.12	President's Prize	50.00
			8,184.67
		Bank Balance Dec. 31/69	4,943.64
		Less Cheques Outstanding	300.00
			12,828.31
		Bonds	400.00
		Investment Certificate	670.81
			13,899.12

Audited and found to be correct:

D. W. Wright

(signed)

B. E. Saunders

January 22, 1970

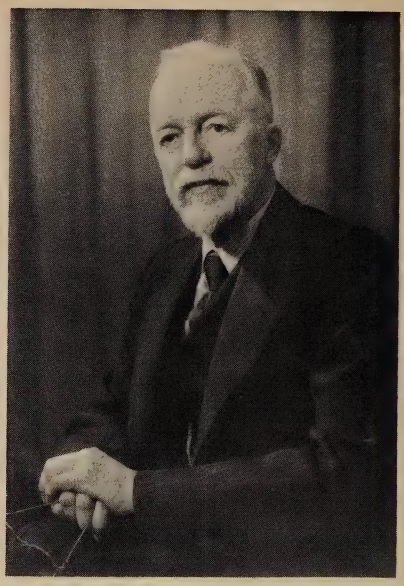
APPENDIX II

PRESIDENT'S PRIZE

Nine papers were presented by university students at the 106th Annual Meeting in the ninth annual competition for the President's Prize (see students and titles above). The judges were W. F. Baldwin, D. G. Peterson, and C. R. Sullivan. The prize was awarded to W. D. Blaine, University of Guelph.

Wilfred Dale Blaine was born at Elgin, Ontario in 1942. He entered Lakehead University in 1962 and received the B.Sc. degree from that institution in 1965. He enrolled for one year in 1966 at the University of Guelph and in 1967 taught high school at Delhi, Ontario. During 1968 and 1969 he worked toward the M.Sc. degree in Insect Physiology at the University of Guelph under the direction of Dr. S. E. Dixon, and received the degree in 1969. He is currently continuing studies for a Ph.D. degree at the University of Guelph.

V. IN MEMORIAM



EDMUND MURTON WALKER
1877 — 1969

Dr. Edmund M. Walker, Professor Emeritus of Zoology in the University of Toronto, died at Toronto on February 14, 1969, following an illness of several years. He was 91 years old.

Edmund Walker was one of the pioneers of Canadian entomology, and his career has been an important part of its development for more than 60 years. His boyhood interest in insects was encouraged by William Saunders; and in 1910, while a young zoology professor at the University of Toronto, he succeeded C. J. S. Bethune as editor of *The Canadian Entomologist,* fulfilling the duties of that position until 1920. Dr. Walker was one of the first entomologists in both the university and museum fields in Canada, and he continued to contribute to both of them throughout his long career. He served as president of the Entomological Society of Ontario from 1910 to 1912. Over the years, the standard of excellence set by his own work in entomology brought to him recognition as one of Canada's most respected zoologists. He received honors from many quarters. In the Entomological Society of America he served as vice-president in 1917, president in 1939, and later was appointed an honorary member. He was an honorary member of the Royal Canadian Institute, and a corresponding member of the American Entomological Society and of the Academy of Natural Sciences in Philadelphia. He became a Fellow of the Royal Society of Canada, and in 1960 was awarded the Society's Flavelle Medal for outstanding work in science. He was an honorary vice-president of the Tenth International Congress of Entomology held in Montreal in 1956. He received honorary membership in the Canadian Society of Zoologists. He was one of the first to be accorded honorary membership in the newly constituted Entomological Society of Canada in 1958; *Grylloblatta campodeiformis* Walker was incorporated into the Society's official emblem. When the Centennial meeting of the Entomological Society of Canada was held in 1963 at Carleton University, a special convocation was held at which the degree Doctor of Science *honoris causa* was conferred upon Edmund Walker as one of Canada's most distinguished entomologists.

Born in Windsor, Ontario, on October 5, 1877, Edmund Walker was the second of seven children of Byron Edmund and Mary Alexander Walker. His father was a man of energy and broad intellectual interests who rose from the position of discount clerk to become president of the Canadian Bank of Commerce, one of the country's largest national banks.

From the prominent position he enjoyed in financial circles, Byron Edmund, later Sir Edmund, Walker was able to exercise his other interests to aid in the establishment of a number of educational and cultural institutions in Canada; among these, interestingly enough, was the Royal Ontario Museum.[1]

Following graduation in Natural Science in 1900 from the University of Toronto, young Edmund Walker went on to complete a course in medicine, to serve his hospital internship at the Toronto General Hospital, and to become a fully qualified medical practitioner. This was largely at his father's persuasion, but when it was clear that even then he had generated no real interest in medicine, it was agreed that he should undertake a career in the field which always had held his enthusiasm — biology. Following a year in the Department of Zoology at Toronto under Ramsay Wright, he studied invertebrate zoology at the University of Berlin. Dr. Walker was appointed as a lecturer in invertebrate zoology at the University of Toronto in 1906, and he remained on the staff for the whole of his career until his retirement in 1948. He served as head of the Department of Zoology for the last 14 years of that period.

Dr. Walker's early studies were centered upon the systematics of the Canadian Orthoptera, and he began in 1897 a series of faunal papers in *The Canadian Entomologist* and the *Proceedings of the Entomological Society of Ontario*. This background, along with his university teaching in invertebrate morphology, gave him a clear grasp of the evolutionary implications of the comparative morphology of insects. Thus, he was well prepared to see at once the significance of the remarkable *Grylloblatta campodeiformis* Walker, the first living representative known in this primitive group, which he discovered in 1913 on Sulphur Mountain at Banff, Alberta. Arising out of this discovery was an important series of papers on the comparative morphology of the orthopteroid insects in general, and on *Grylloblatta* in particular, which he produced over the years that followed.

Among colleagues and students, however, Edmund Walker was known best for his intensive studies of Canadian dragonflies. Many of his summers were spent in one part of Canada or another collecting and observing these insects. Even from the very beginning his papers reflected the conviction that knowledge of the larval stages was not only an essential part of the systematics of the group, but also the necessary route to an understanding of the ecology of each species. His monographs of North American species of the genera *Aeshna* and *Somatochlora* are still highly regarded.

In addition to these major aspects of his work, Dr. Walker also studied the biology of the fly *Wohlfahrtia vigil,* and its involvement in cutaneous myiasis in humans. He published short papers on several other groups, a reflection of the very wide knowledge he had developed about the systematics of invertebrate animals.[2] He was a competent field botanist as well.

Professor Walker was the first invertebrate zoologist, and for many years the only one, at Toronto. It was his responsibility to provide for expanding requirements on all sides — general entomology, forest entomology, parasitology, introductory invertebrate systematics. Gradually these were taken over by newer members of the staff, but the course for which he became best known to students and taught until he retired, was his advanced invertebrate zoology, dealing with the morphology and phylogenetic relationships of the Arthropoda. His own knowledge of arthropod morphology was encyclopedic, and with it he combined his life-long interests and field observations in terrestrial, freshwater, and marine arthropod groups. These assets he was able to supplement with his native talents for drawing and accomplished mimicry of the sounds and actions of small creatures, and with a broad cultural background. Students took with them to all parts of Canada fond memories of his lectures and gentle personality.

Although Edmund Walker was a university professor for the whole of his career, there was yet another facet of his activities. When the Royal Ontario Museum was established in Toronto in 1914, on the edge of the University campus, various members of the University's departments whose disciplines were to be represented in the Museum volunteered to oversee the installation of the first exhibits and study collections. Dr. Walker took responsibility for the invertebrate work, and later served as assistant director of the Museum of Zoology from 1918 to 1931. He took an active part in the affairs of the new museum: choosing and guiding staff members, setting up some exhibits himself, contributing to the growth and upkeep of the study collections, and combining his own field work with that of the Museum. When mounting university responsibilities forced him to give up this post, he was appointed Honorary Curator of Invertebrate Zoology in the Museum, a position he held until his death. Dr. Walker gave his personal collections and library to the Museum, and after his retirement from the University he began in 1949 a period that was to run for nearly 15 years of almost daily atttendance at his office in the Department of Entomology. Here he began to organize the data from his collection of dragonflies and a lifetime of field observations into his monumental monograph,

[1]Further details of these and other accomplishments of this remarkable individual are available in: *Sir Edmund Walker,* by G. P. de T. Glazebrook, Oxford Univ. Press, 160 pp., 1933.
[2]A full listing of Edmund Walker's published works, along with an autobiographic sketch and appreciations of his work by colleagues, is available in: *Centennial Entomology in Canada, 1863-1963: a tribute to Edmund M. Walker.* 1966. Ed. by Glenn B. Wiggins, Univ. Toronto Press. 94 p.

The Odonata of Canada and Alaska. Volume I was published in 1953 when he was 76 years old; five years later Volume II appeared. He began the third and concluding volume at the age of 82, but after completing a large part of the manuscript, illness forced him to give up work on it in his 86th year. The final volume is being completed by Dr. Philip Corbet.

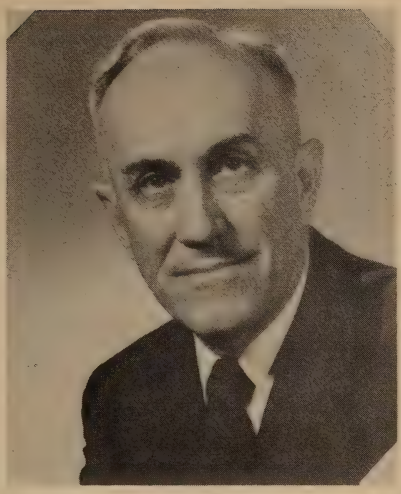
Dr. Walker's interests were extended in several other directions, too. He was a founding member, and later president of the Toronto Field Naturalists' Club, and served as president and director of the Federation of Ontario Naturalists. For a number of years he attended the Summer Nature Camp of the Federation of Ontario Naturalists as a group leader. He was an amateur painter, and keenly interested in the development of Canadian painting.

Professor Walker's wife, Dr. Norma Ford Walker, professor emeritus of human genetics at the University of Toronto, died a few months before he did. His first wife died in 1941, and he is survived by four children and fourteen grandchildren.

To his friends and colleagues, Edmund Walker was a man of charm and interest. Although possessing a rather remote demeanor, he was quick to share his enthusiasm for living things with all who were genuinely interested. He holds a special place in the memories of all who knew him.

Edmund Walker's standards for himself were unfailingly high, and he met them in everything he undertook. As entomologist, professor, museum curator — his life was long, full and productive, and rich in its satisfaction with tasks well done. His contribution to Canadian biology is very large. But to the many biologists whose careers he touched personally, Edmund Walker's life represents more even than that. To them his example means unwavering curiosity about all plants and animals; it means teaching oneself to recognize living things as though they were personal acquaintances, knowing something of the peculiar characteristics and family background of each one, and sensing a faint touch of exhilaration when one long unseen is seen again; it means teaching oneself to move in natural communities with a familiar ease that comes only from knowing the residents, one by one. With quiet humility, Edmund Walker learned to comprehend his environment as few men ever have.

Glenn B. Wiggins, Curator, Department of Entomology,
Royal Ontario Museum, Toronto, Ontario



GEORGE WISHART
1896 — 1970

Mr. George Wishart, entomologist, conservationist, civic and community leader, died on February 23, 1970. He had suffered for some time with a heart condition and his last illness was brief.

Mr. Wishart was born at Carp, Ontario, and received his early education in Renfrew and Arnprior. After graduation from Arnprior High School in 1915, he obtained a teacher's certficate at the Ottawa Normal School and taught in Ottawa Valley schools until 1920. He entered the Ontario Agricultural College in 1920 and specialized in entomology. While at O.A.C. he was very active in campus activities. As a student he obtained summer employment with the Ontario Department of Agriculture. After graduating from O.A.C. in 1924, he was employed for a year by the United States Department of Agriculture, but was forced to resign because of illness. He was appointed to the staff of the Entomology Laboratory at Chatham, Ontario, in 1927, to investigate the biological control of the European corn borer. In 1934-35 he attended Macdonald College and received his M.Sc. degree.

In 1929, Mr. Wishart was among the scientists to move from Chatham to Belleville with Mr. A. B. Baird. At Belleville he was made responsible for all biological control projects on field crop and garden insects. His mechanical knowledge and woodworking skills enabled him to develop special techniques for the propagation of parasites, host insects, and host plants. He played a major role in the design of air conditioning and other specialized equipment in the quarantine laboratory constructed in Belleville in 1935 for research on biological control agents. The successful biological control of several species of insect pests can be directly attributed to the work of Mr. Wishart and his assistants.

In 1956 the organization and functions of the Research Institute at Belleville changed and Mr. Wishart entered a new and challenging field of research — the responses of insects to sound. It is a tribute to his ability and versatility that in the relatively short time from this change to his retirement in 1961, he received international recognition for his published results in this field.

Mr. Wishart was the author or coauthor of 31 publications, many of his early ones appearing in the *Proceedings of the Entomological Society of Ontario*. He was a Director of this Society for the terms 1941-42, 1945-46, and 1953-54.

Mr. Wishart's contributions to Canadian agriculture did not prevent him from taking an active interest in community affairs. Conservation was part of his fiber, and he was a member of the Soil Conservation Society of America. After joining the Moira River Conservation Authority he entered wholeheartedly into the work of that organization and became Chairman of the Board. During the summer of 1969 he and Mrs. Wishart spent many long hours in the restoration of the house and furnishings at O'Hara Mill Conservation Area. He was an ardent trout fisherman, and was a Director of the Belleville Fish and Game Association.

In his civic life he was active in many organizations for the betterment of his fellow man. He was a longtime member of the Canadian National Institute for the Blind and held all executive offices in that organization, and received its citation for 25 years of continuous service.

He was an appointed member of the Vocational Advisory Committee of the Belleville Board of Education and an elected member of the Board from 1945-52, and Chairman in 1947. In 1952 the Belleville Board of Education was replaced by the Bay of Quinte High School Board; Mr. Wishart remained an elected member of this Board until 1957 and was Chairman in 1954.

In 1958 Mr. Wishart was elected Alderman of the City of Belleville, a position he held for six years. During his term he was appointed to the Hospital Board of Governors and also to the Children's Aid Society where he served for many years as a Director and Vice-President.

His work in the community was recognized by the Belleville Jaycees when in 1965 they named him Citizen of the Year.

Mr. Wishart is survived by his wife, the former Lois Christina Keatley, three daughters, and five grandchildren.

M. G. Maw, Research Institute, Canada
Department of Agriculture, Belleville, Ontario

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of the

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Volume One Hundred and One

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I. REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

INSECTS OF THE SEASON 1970 RELATED TO FRUIT, VEGETABLES, FIELD CROPS AND ORNAMENTALS

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Abstract

A resume of the occurrence in Ontario in 1970 of several species of insects affecting fruit, vegetables, field crops and ornamental plants

Fruit

No serious infestations developed in 1970 that were not fairly well managed by control programs. Insects that caused no serious problem included the codling moth, *Carpocapsa pomonella* (Linneaus), apple maggot, *Rhagoletis pomonella* (Walsh), cherry fruit flies, *Rhagoletis* spp., and red-banded leaf roller *Argyrotaenia velutinana* (Walker).

The pear psylla, *Psylla pyricola* Foerster, developed to large numbers in a few orchards, possibly as a result of the development of a strain resistant to control by Guthion. The European red mite, *Panonychus ulmi* (Koch), continued to be the most important pest of tree fruits, especially apples. The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), injured apples, potatoes and strawberries. The sap beetle, *Glischrochilus quadrisignatus* Say, continued to cause an important problem on raspberries and, in some areas, on tomatoes. The grape berry moth, *Paralobesia viteana* (Clemens), caused extensive damage in some vineyards.

Vegetables

Cutworms were troublesome on several crops at various times during the summer. The red-backed cutworm, *Euxoa ochrogaster* (Guenée), was the principal species on onions and carrots at Bradford Marsh in June, the area where the greatest damage occurred. The black cutworm, *Agrotis ipsilon* (Hufnagel), was the principal species at the Leamington and Erieau Marshes. Cutworms of various species caused damage on tobacco, tomatoes and other vegetables in many areas. Cutworm damage similar to that of 1969 occurred in some fields of rutabagas in Huron County in August.

Two species of thrips, *Thrips tabaci* Lindeman and *Frankliniella tritici* (Fitch) infested asparagus at cutting time in the Georgian Bay area. All were migrant adults from various other plants. Although there was no feeding damage on the asparagus, they lodged under the bracts. This resulted in the contamination of a considerable amount of processed asparagus.

The cabbage maggot, *Hylemya brassicae* (Bouché) caused damage in seedbeds and on cabbage, cauliflower, and rutabagas in the field only where an adequate program was not used. The cabbage looper, *Trichoplusia ni* Hübner, caused a problem on late cabbage, spinach, and celery with populations similar to 1969. The Colorado potato beetle *Leptinotarsa decemlineata* (Say) was reported in several potato-growing areas in greater numbers than last year. Damage from the second brood of the European corn borer, *Ostrinia nubilalis* Hübner, increased considerably. The sweet corn growers were able to obtain fair control. Some field corn was heavily infested. The crop loss on field corn was variable and difficult to estimate. The corn borer attacked peppers severely, causing considerable crop loss. Aphids were more troublesome than usual on tomatoes, lima beans and cucumbers.

Field Crops

The alfalfa weevil, *Hypera postica* (Gyllahal), continued to spread and is established in 40 counties. This insect caused damage at the economic level in the first two tiers of counties bordering Lake Erie, in all counties adjacent to Lake Ontario and in Leeds, Grenville, and Dundas counties.

The cereal leaf beetle, *Oulema melanopus* (Linneaus), was found in 25 counties in southwestern Ontario. It has spread as far east as Northumberland County, but has not caused crop loss to date.

The northern corn rootworm, *Diabrotica longicornis* (Say), caused some damage in southwestern Ontario. No damage was reported east of Wellington County.

Ornamental Plants

Many requests for information concerning insects of ornamental trees, shrubs and flowers were received. However, except for defoliators and a few others, the problems were not important.

The honey locust pod gall, *Dasyneura gleditshiae* O.S., caused considerable defoliation on Moraine locust and its ornamental varieties in late June. Infestations were normal during the rest of the season. The elm leaf miner, *Fenusa ulmi* Sundevall, on camperdown elm, and the birch leaf miner, *Fenusa pusilla* (Lepeletier), were important on these trees in landscape plantings. The caterpillar, *Yponomeuta multipunctella* Clemens on *Euomymus europea* completely defoliated this species as in 1969, except where the shrub was protected with malathion. This shrub has been almost eliminated by this caterpillar from natural surroundings at Guelph. The oak skeletonizer, *Bucculatrix ainsliella* Murtfeldt, was common on oak in several areas. The mountain-ash sawfly, *Pristiphora geniculata* (Hartig) defoliated the lower branches on many mountain ash.

INSECTS AND OTHER ARTHROPODS OF IMPORTANCE DURING 1970 IN HOUSEHOLDS AND ON LIVESTOCK IN ONTARIO

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Abstract

A resume of the occurrence in Ontario during 1970 of certain species of insects and other arthropods in houses and on livestock.

Household

Fleas, *Ctenocephalides spp.*, were the most commonly reported insects in households during the year. In many cases the infestations were severe and very persistent. Bedbugs, *Cimex lectularius L.*, were much more numerous than they have been for many years. Cluster flies *Pollenia rudis* (Fabricius), appeared in large numbers in many homes during the late winter and early spring, and heavy infestations of larder beetles, *Dermestes lardarius L.*, observed mainly in the larval stage, seemed to coincide with cluster fly populations. European earwigs, *Forficula auricularia* (Linnaeus), were reported from widespread areas and caused concern in and around houses. Millipedes, *Narcus spp.*, were reported from many areas and sometimes in large numbers. Sowbugs, *Oniscus spp.*, were reported occasionally as being found in damp basements and storage areas. Many species of ants, in particular *Camponotus spp.*, were found in city homes, and summer cottages.

In kitchens, saw-toothed grain beetles, *Oryzaephilus surinamensis* (Linnaeus), were common and were reported many times during the year.

Livestock

Face flies, *Musca autumnalis* (DeGeer), were the most common pests of livestock. This fly increased in numbers and was reported from a much more widespread area in 1970 than in the previous year. Many reports were received of large numbers on horses. Horn flies, *Haematobia irritans* (Linnaeus), were noted, but never in large numbers. Warble flies, *Hypoderma spp.*, were observed in beef cattle during the late winter and early spring.

PLANT PARASITIC NEMATODES OF ECONOMIC IMPORTANCE IN ONTARIO

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Abstract

Seven genera of plant parasitic nematodes, including large numbers of *Pratylenchus* and *Paratylenchus* spp., were present in agricultural soil samples from northern Ontario. *Helicotylenchus digonicus, Paratylenchus projectus,* and *Pratylenchus* sp. together with *Heterodera avenae,* were associated with damage to cedar, rhubarb and corn, respectively. Field studies established a correlation between levels of *Meloidogyne hapla* and *Pratylenchus penetrans* and losses in several vegetable crops. A fall preplant soil fumigation with Vorlex tripled winter rhubarb root weight.

There are several plant parasitic nematodes in Ontario soils that have an important economic impact on crop production. These are the root-lesion nematode, *Pratylenchus* Filipjev; the root-knot nematode, *Meloidogyne* Goeldi; the cyst nematode, *Heterodera* Schmidt; the dagger nematode, *Xiphinema* Cobb; the bulb and stem nematode, *Ditylenchus dipsaci* (Kühn) Filipjev, and the pin nematode, *Paratylenchus* Micoletzky.

C. Warner of the New Liskeard College of Agricultural Technology collected 16 soil samples from hay and pasture, and from corn, oats and barley fields at Powassan and Trout Creek in Parry Sound District, Astorville in Nipissing District, and Thunder Bay and Kakabeka Falls in Thunder Bay District. Seven genera of plant parasitic nematodes were extracted at Vineland from these samples: root-lesion, root-knot, cyst, pin, dagger, spiral (*Helicotylenchus* Steiner), and stunt nematodes (*Tylenchorhynchus* Cobb). The lesion and pin nematodes were most prevalent and each occurred in 13 of the 16 samples. Up to 13,000 and 6,400 nematodes per pound of soil, respectively, were recovered from individual samples. The size of the populations exceeded expectation as the northern climate had been thought to be too harsh for survival of large populations.

The spiral nematode, *Helicotylenchus digonicus* Perry, was found associated with a progressive decline in vigor of the cedar (*Thuja occidentalis*) cultivar Brandon in a nursery in Saskatchewan. The pin nematode, *Paratylenchus projectus* Jenkins, was associated with a yield reduction of 20 to 30 tons of fresh rhubarb, worth $900, in a 2-acre planting on Vineland silt loam. Stunting of plants was associated with populations in excess of 20,000 nematodes per pound of soil. The oat-cyst nematode, *Heterodera avenae* Wollenweber,

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[1] Contribution No. 197

continued to be detrimental to oats and corn in areas of southwestern and eastern Ontario where the problem has been reported previously (Olthof *et al.* 1969). An association of the oat-cyst nematode and the root-lesion nematode has been found on corn near Lindsay, Ontario. Sampling evidence suggests that the lesion nematode may contribute to the stunting and the apparent symptoms of phosphorus deficiency characteristic of high oat-cyst nematode populations.

From May until August, six vegetables were tested in the field against five levels of the northern root-knot nematode, *M. hapla.* All crops suffered considerable damage at the highest nematode density (8,100 per pound of soil) with lettuce, potato, and onion yields being reduced by 25, 46 and 64%, respectively. A similar test with the root-lesion nematode, *Pratylenchus penetrans,* was conducted in the fall. The highest nematode level reduced yields of lettuce, beets, and spinach by 40, 30 and 20%, respectively.

A fall preplanting application of Vorlex on a clay loam winter rhubarb field resulted in a tripling, over a two-year period, of the average weight of root for the forcing shed. The rapid increase in preplant soil fumigation during the past few years has been paralleled to some degree by an increase in postplant applications of nematicides, particularly in nurseries, orchards, and greenhouses. Although several promising new postplant chemicals are now being tested, only one chemical, 1,2-dibromo-3, chloropropane (Nemagon, Fumazone), is registered for use in Canada. The use of preplant soil fumigation, followed by the establishment of a relatively poor host crop and the periodic use of postplant nematicides, appears to be an effective root-lesion nematode control program that will reduce replant problems and increase tree longevity and fruit yield in peach and cherry orchards.

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NOTEWORTHY FOREST INSECTS IN ONTARIO IN 1970

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Abstract

This review provides a capsule record of those forest insects that for a variety of reasons were considered important or noteworthy pests, as reported in the 1970 Annual Survey Report (Sippell *et al,* in press). Infestations of major pests are delineated generally, new or unusual infestations are pointed out, and where necessary the spread of introduced pests is described.

Indigenous Insects

Coniferous Hosts

The spruce budworm, *Choristoneura fumiferana* Clemens, continued to be the most important and destructive forest insect pest in Ontario in 1970. The three rather distinct cells in southeastern, northeastern, and northwestern Ontario reported previously persisted and enlarged. In southeastern Ontario, the area of moderate to severe defoliation, 2,500 square miles, was more than twice that in 1969. New areas of infestation were mapped along the Ottawa Valley from Pembroke northwest to Deux Rivières, in the vicinity of Opeongo Lake and Whitney in Algonquin Provincial Park, east

of Bancroft, and between Fenelon Falls and Gooderham. Damage to spruce and balsam was particularly severe in the Chalk River-Deep River area where a mass invasion of moths occurred in 1969. Hatched-egg counts indicate a potential for severe damage in 1971 and an extension of damage, particularly in Algonquin Provincial Park.

In northeastern Ontario, the area of moderate to severe defoliation almost tripled in size over 1969, encompassing an area of approximately 8,200 square miles. Many pockets of infestation in 1969 had coalesced by 1970 and the large infestation around Chapleau spread southwestward a distance of 60 miles to Wawa and into the Lake Superior Provincial Park. On the basis of hatched-egg counts, infestations are expected to continue at the same intensity with an enlargement of numerous infestations. Some stands have now suffered moderate to severe defoliation for four years and mortality and top killing can be expected.

In northwestern Ontario, early detection through intensive monitoring, and subsequent prompt chemical control action, where required, appears to have kept the area under attack to a minimum. However, damage to stands of young balsam and spruce was detected, west of the 1969 infestations at Northern Light, Granite and Gunflint lakes, along the International Border in the vicinity of Poohbah and Tanner lakes. Elsewhere, only extremely low numbers of larvae could be found.

A total of seven aerial spraying operations were carried out over some 23,000 acres in all segments of the outbreak, under a cooperative arrangement between the responsible federal and provincial agencies.

Only a few remnants remained of the previous extensive infestations of the jack pine budworm, *Choristoneura pinus pinus* Freeman. An unusual medium to heavy infestation on Scots pine in Gordon Township on Manitoulin Island recurred for the third consecutive year. Medium to heavy infestations recurred along the French River. Jack pines growing on poor sites in the northwest corner of Georgian Bay Provincial Park suffered severe tree and tree top mortality because of repeated defoliation. Moderate to severe defoliation occurred in 3,300 acres in the Lake Traverse area where three years of severe defoliation resulted in 20% of the trees being killed and another 30% having dead tops.

The balsam fir sawfly, *Neodiprion abietis* complex, continued to ravage balsam fir trees along the Ottawa River between Pembroke and Arnprior and near Hawkesbury as well as along the Madawaska River Valley. The larch needle worm, *Zeiraphera improbana* (Walker), a little-known species, caused severe defoliation in a 200-acre larch stand near Wawa. An unidentified cecidomyid that fed inside the needle sheath at the base of the current year's needles, causing needle drop in late summer, and reported last year for the first time, caused severe damage in Scots pine Christmas tree plantations in six townships east of Smith's Falls. The four species of cedar leaf miners, *Argyresthia thuiella* Packard, *A. aureoargentella* Brower, *A. freyella* Walsingham, and *Pulicalvaria thujaella* Kearfott, were abundant in southeastern Ontario especially in the Kemptville-Merrickville area, and increasing population levels were recorded in the central parts of the Lake Simcoe and Lake Huron districts. Infestations of the Swaine jack-pine sawfly, *Neodiprion swainei* Middleton, have occurred intermittently since 1946 on open-grown trees on islands and along the shores of lakes in the Lady Evelyn Lake area west of Haileybury. In 1970, two of the heaviest infestations known in this general area occurred in closed stands of pole-size jack pine, giving rise to concern because of the damage caused by this sawfly in closed stands in Quebec.

Broad-leaved Trees

Trembling aspen in more than 20,000 square miles of northern Ontario suffered moderate to severe defoliation by three defoliators during the early summer. The most abundant species was the noctuid, *Enargia decolor* Walker, which was present primarily in northeastern Ontario, in a massive infestation extending in a band 160 miles long and 60 to 120 miles wide from the Ontario-Quebec border between Lake Abitibi and Temagami as far west as Missinaibi Lake and Chapleau. Within this huge area the large aspen tortrix, *Choristoneura conflictana* Walker, was also present in damaging numbers. Other infestations of the large aspen tortrix were recorded in much the same area as in 1969, along the North Channel, northeast of Lake Superior, west of Thunder Bay where infestations have persisted for three years, and along the Pigeon River adjacent to extensive infestations in Minnesota.

Infestations of the forest tent caterpillar, *Malacosoma disstria* Hübner, south of Elliot Lake collapsed and negligible defoliation occurred. On the other hand, the infestation north and west of Fort Frances appeared to be increasing slightly in both extent and intensity and fall egg counts indicated that moderate to severe defoliation will persist in 1971. In 1970, the most widespread outbreak, in almost 30 years, of the birch skeletonizer, *Bucculatrix canadensisella* Chambers, was recorded. Moderate to severe defoliation occurred throughout an area of 22,900 square miles in northwestern Ontario exclusive of a sizable area immediately west of Lake Superior that was not mapped. In addition, 30 other medium to heavy infestations of varying size, totalling 4,000 square miles in area, were widely scattered across the remainder of the province. Four species of defoliators of maple were of special interest because of collapsing population levels in one instance and rising trends in the others. The large infestation of the saddled prominent, *Heterocampa guttivitta* Walker, extending from the western part of Algonquin Provincial Park and north of Huntsville across Highway 11, collapsed. Infestations, generally in other stands than in the previous year, continued on the Bruce Peninsula and on islands in Georgian Bay. The green-striped mapleworm, *Anisota rubicunda* Fabricius, has been at endemic levels since the outbreak in the late 1940's and its general decline through the 1950's. Since 1967 when 2 samples were received, collection numbers have increased each year, and in 1970, 27 were received. A few colonies of larvae could be found on maple from Sault Ste. Marie east to the Ottawa River. Another example is the maple trumpet skeletonizer, *Epinotia aceriella* Clemens, which was collected more frequently than in any year since 1960 along the North Channel and at numerous locations in southern Ontario. Heavy infestations of the maple leaf cutter, *Paraclemensia acerifoliella* Fitch, were the first reported since 1965 when infestations of this pest that occurs primarily in southeastern Ontario died out. Damage to black cherry by a little-known looper, *Hydria prunivorata* Ferguson, was sufficiently severe to be detectable by aerial observation on both sides of Highway 11 from Gravenhurst to North Bay, and heavy feeding by lacebugs, *Corythucha* spp., caused premature leaf drop on elm and oak in southeastern Ontario.

Introduced Insects

Coniferous Hosts

Despite intensive searches, no infestations of the European pine sawfly, *Neodiprion sertifer* Geoffroy, were found outside of the urban area infestations in Sault Ste. Marie and Ottawa, nor could it be found in North Bay in 1970 despite its occurrence there in 1969. Population levels increased only slightly on Manitoulin Island but unlike previous years, no larvae killed by virus could be found there. Of significance was the discovery in Sault Ste. Marie of a colony of the introduced pine sawfly, *Diprion similis* (Hartig), and the discovery of a 150-square-mile infestation of this pest on mature white pine on islands at the west end of Rainy Lake, well outside the known range of this pest in Ontario (Sippell, 1966). The origin of the Sault Ste. Marie material is speculative since the closest known source is 50 miles to the south in Michigan (personal communication P. R. Flink, Michigan, Department of Natural Resources). The infestation on Rainy Lake has obviously been present more than one year and appears to be an extension of the adjacent Minnesota infestation (Beach, 1970). It is now apparent that the introduced pine sawfly can survive in more northern areas than was previously thought.

Broad-leaved Hosts

The first known instance of long-range dispersal in the province of the smaller European elm bark beetle, *Scolytus multistriatus* (Marsh), came to light in June when larvae, pupae, and adults were found in the city of Sault Ste. Marie in logs that had been snow-covered during the previous winter. Whether or not it can survive in this area is under investigation by Regional research staff. The closest known source of this material is 175 and 135 miles away in Ontario and Michigan respectively. Therefore, it is reasonable to assume that this occurrence resulted from the movement of infested elm into the city. In southern Ontario in the main body of infestation, slight northward advances were made near

Havelock. With the finding of the mountain ash sawfly, *Pristiphora geniculata* (Hartig), near Thunder Bay, the suggestion (Rose, 1970) that its spread into northwestern Ontario would be rapid is being borne out. Numerous extensions were recorded across its northern range limit. Only slight extensions were established in the range of the birch leaf miner, *Fenusa pusilla* (Lepeletier), north of Lake Superior and southwest of Lake Nipigon.

A chemical control operation aimed at the containment of the gypsy moth, *Porthetria dispar* Linnaeus, in southeastern Ontario, was carried out by the Plant Protection Division, Canada Department of Agriculture. Areas treated included part of Wolfe Island and a small area on the mainland near Kingston. Their fall surveys revealed the presence of eggs on Wolfe and Howe islands and in a small area near Joyceville.

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A SURVEY OF INSECTS INFESTING VEGETABLE CROPS IN SOUTHWESTERN ONTARIO, 1969[1]

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Abstract

In southwestern Ontario at least 105 species of insects have been known to infest vegetable crops. A survey made in 1969 showed that some 15 species are thought to be of immediate concern. For convenience these are grouped into three categories: (1) insects that require research in depth, including 4-spotted sap beetle (on tomatoes), aphids (several species), tarnished plant bug and cabbage maggot (on rutabagas); (2) insects that frequently occur in outbreak numbers and are a constant threat, including cabbage looper, European corn borer, carrot rust fly, potato leafhopper, and the Colorado potato beetle; (3) insects of unknown or questionable status, of concern to growers, but usually of local importance, including subterranean cutworms, corn earworm, field cricket (on tomatoes), thrips, and whitefly (in greenhouses). To these may be added slugs, which are becoming increasingly important.

About 90% of the vegetable crops grown in Ontario are found in the area south of Orillia and west of Whitby. These crops represent an annual gross product of nearly $50 million. All of them are subject to insect attack, but the status of some of the different vegetable insect pests is uncertain. In 1969 the writer surveyed this area to ascertain the pests associated with vegetables, and to determine their present economic status.

There are nine main vegetable-growing regions in southwestern Ontario. The names of these regions, the crops grown and the approximate acreages, are given in Table I. In addition, most of the sweet corn grown for processing and a high percentage of the processing peas are grown in this area. The figures for these two crops are unavailable in break-down form.

Many people associated with vegetable production were interviewed during this

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[1] Stationed at Chatham, Ontario

Table I. Main vegetable crops, by districts, grown in southwestern Ontario*

	Guelph	London	Niagara	Norfolk and Haldimand	Toronto	Bradford Marsh	Burlington	Essex and Kent	Georgian Bay
Asparagus	60	130	90	280	110		220	665	500
Beans, pod		22		10	400		280	175	
Beets	3	36	10		100	53	62	590	
Cole crops	310	93	80	310	700	224	404	1,050	105
Carrots	90	200	30	15	200	2,188	120	195	
Celery		45	44			266	60	95	
Cucumber	15	18		55	150		80	150	
Corn, market	1,040	120	75	600	250		120	1,350	20
Corn, processing		(21,000–Total)							
Lettuce		115	42		50	899	80	175	
Onions, bunching		6	30		100		30	80	
Onions, dry		702	53			2,083		1,379	
Peas		(19,500–Total)							
Peppers	5	7	12	245	20		125	570	
Radish		25	27		160	35	50	75	
Rutabagas	2,900	1,525		35	350		300		
Spinach		12			200		185	105	
Tomato, market	24	42	325	200	400		700	2,550	
Tomato, processing	66	1,088	600	1,705	16		281	17,672	

*Ontario Department of Agriculture and Food Publication 20, Agricultural Statistics for Ontario, 1967.

survey. These comprised growers, extension personnel, processing officials, and research workers. The evidence collected has been carefully considered and divergent views have been taken into account.

The actual loss to insects is not usually great on farms operated by the better growers, but these farmers know that the potential for damage is always present and they are geared to a preventative program. Even then, unexpected insect outbreaks may occur. Average growers usually, and poor growers at all times, use control measures only after serious damage occurs; frequently this is too late to be of value.

The survey has established that at least 105 different species of insects have been known to attack vegetable crops in southwestern Ontario. The total is actually higher because authors have frequently lumped certain species under broad headings. Thus we have wireworms, cutworms, white grubs, and so forth. A list of the known species of injurious insects is appended to this report. The Canadian Insect Pest Review has been most helpful in obtaining this information.

Compilations consulted included the earlier bulletins of Caesar (1938) and Dustan (1932) for historical perspective, and the more recent publication of Goble (1960). A review of the literature for the past decade reveals that over 100 workers have written about vegetable insects in Ontario. A number of these are only references to species and some deal only with physiology or taxonomy. In the main, however, the references dealing with economic species of interest are numerous.

Twenty-one insects, forming 28 crop-pest associations, are economically important (A, Table II). These frequently cause economic loss and are present every year in varying degrees. They require constant vigilance by the vegetable growers. Twenty-three insects, or insect-complexes, forming 35 crop-pest associations, cause occasional damage and rarely warrant control measures (B, Table II). Since they are not present on a particular crop every year, they are frequently forgotten or overlooked. When this happens, damage may be severe, but it is usually local. More than 40% of the insects associated with vegetable production in the province may be regarded as relatively innocuous. They are of the nuisance type, and seldom require control measures. Sometimes these insects are accidental introductions; for example, in October 1969 the beet armyworm, *Spodoptera exigua* (Hübner), was found attacking celery in the Erieau marsh. It is thought that eggs of this insect had been brought north on chrysanthemum cuttings imported from Georgia. Moths, in turn, had escaped from local greenhouses to open fields. In 1953 a massive flight of *Helicoverpa (Heliothis) zea* (Boddie) caused severe damage in tomatoes in Essex and Kent counties. Corn, the usual host plant, had matured very early that season, so the moths laid eggs on the alternate host, tomato. This is most unusual in Ontario, but quite common farther south where this insect is also known as the tomato fruitworm.

Some insects, formerly regarded as of secondary or even minor importance, are now serious pests in Ontario vegetable production. One of these, the 4-spotted sap beetle or picnic beetle, *Glischrochilus quadrisignatus* Say, is presently causing the most concern. This beetle is attracted to decaying fruits and vegetables. It is frequently found in overripe raspberries and on the tips of ears of corn previously damaged by bird feeding. Latterly, however, it has appeared in large numbers in tomato fields during the harvesting period. These insects are especially attracted to cracked fruits. They may be carried into the processing factories and, inadvertently, appear in the packaged product. These insects are of concern to grower, processor, and consumer.

In order to assess the relative status of the more important insect pests, a summary is presented of each crop.

Tomatoes

From a monetary standpoint tomatoes are the most important vegetable grown in Ontario. About 95% of the crop is grown in the area under discussion; Kent and Essex counties alone grow 75% of the total crop. Tomatoes are more prone to disease than insect damage, but certain species are a constant threat. Sap beetles, are an important pest, not so much because of damage caused, but because insect fragments may be incorporated into the tomato pack. As pointed out by Foott (in litt.) this insect is most difficult to control. It

would seem that cultural methods at harvest, when these beetles are the greatest threat, are the best way to control them.

Crickets *(Gryllus* spp.) are mainly of concern to growers, rather than processors. They do the greatest damage in Essex County. Ripe fruits are usually attacked, especially along the edges of fields where weeds are most abundant. It is difficult to assess how great a problem crickets represent. They do chew large holes in ripe fruits, and early in the season, when tomatoes are scarce, this is a source of annoyance to the growers. It is doubtful whether crickets constitute a serious threat as the harvest becomes more plentiful. However, most growers, and some processors, regard crickets as the most important pest of tomatoes.

The potato aphid, *Macrosiphum euphorbiae* (Thomas), could be a very serious pest of tomatoes in some seasons. Most growers include an aphicide in the preventative sprays used against diseases. Growers judge present controls to be adequate.

Several species of cutworms attack tomatoes, causing local, but severe, damage. The climbing species can be especially destructive. Only fair control is obtained by the growers who are usually caught unawares when an outbreak occurs.

The tomato hornworm, *Manduca quinquemaculata* (Haworth), is no longer regarded as a serious pest of tomatoes. Today it rarely causes economic loss. The potato flea beetle, *Epitrix cucumeris* (Harris), frequently attacks seedling plants in the spring. In general, growers tend to disregard this insect; possibly it is overlooked, since it usually attacks the plants shortly after planting. Sometimes growth is stunted severely, but generally, plants overcome this early flea beetle damage.

Fruitflies, *Drosophila* spp., formerly caused problems at the processing factories, where insect fragments sometimes appeared in the pack. Fogging trucks and wagons with pyrethrin sprays at unloading stations seems to be a successful control against this insect.

The tomato fruitworm has already been mentioned. The outbreak in 1953 left an indelible mark and established growers are still apprehensive about this insect. Occasionally, the cabbage looper, *Trichoplusia ni* (Hübner), attacks the foliage of tomato plants. Also, the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), sometimes injures young plants before and during the blossoming period. In the Whitby area, mites are reported causing damage to tomato plants.

Sweet Corn

The bulk of the sweet corn in Ontario is grown west of Whitby, with large acreages in Kent and Essex counties, along Lake Erie, and in Middlesex and Huron counties. The European corn borer, *Ostrinia nubilalis* (Hübner), remains the worst pest of this crop. The chief reason for this is poor timing of insecticide treatments by the corn growers, many of whom do not understand the life history of this insect (Wressell and Hudon, 1968). Knowledgeable growers have little trouble controlling the borer. It is of concern to the processing industry since second generation larvae may infest kernels late in the season. Such infested corn sometimes ends up in the processed product, to the consternation of the housewife, and causes a loss in sales of that particular brand. DDT was formerly widely used for borer control, but as of this date (1970), only carbaryl is available, and a certain apprehension is apparent among the growers. However, if properly applied this material gives excellent results.

The corn earworm frequently causes severe damage, and control of this pest is not well developed. As this insect is of southern origin, and appears late in the season, it is frequently overlooked in its early stages. Later, because it enters the ear and is protected there, control is not possible. In some years it causes more actual loss than the corn borer, but it is not so insidious in the type of damage.

The status of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), is uncertain. Sometimes it is responsible for poor pollination; it has also been blamed for stunting the plant and for the production of small ears. In sweet corn, where hand-picking is practiced for the fresh vegetable market, aphid-infested ears have a psychological effect on female pickers and this also adversely affects sale. A few growers resort to spraying, but in the main this aphid is disregarded and treated as a nuisance only.

Various species of cutworms, principally the black cutworm, *Agrotis ipsilon*

(Hufnagel), and the variegated cutworm, *Peridroma saucia* (Hübner), frequently appear in outbreak form. The glassy cutworm, *Crymodes devastator* (Brace) and white grubs, *Phyllophaga* spp., damage corn in land that has been in grass for several years. Armyworms, *Pseudaletia unipuncta* (Haworth), occasionally damage corn, especially if grass is allowed to develop in the field, or pasture is grown nearby. Billbugs, *Spenophorus* spp., of various species, attack corn, particularly that growing in reclaimed swampland or old pastures.

The chinch bug, *Blissus leucopterus* (Say), occasionally caused damage in Essex County before herbicides were in general use, but no reports about this insect have been received in recent years.

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), is an insect of southern origin that migrates northward during late summer and early fall. Sometimes it causes serious damage to late-planted corn. Usually, only the foliage is affected, but in 1969 several hundred acres of sweet corn suffered severe ear damage. If found in time, this insect can be readily controlled.

Sweet corn is usually grown in a rotation but sometimes processing corn has been grown on the same land for several years. Such a crop is subject to attack by the northern corn rootworm, *Diabrotica longicornis* (Say), which is specific to corn. Generally, however, rootworms are of little concern to sweet corn growers. On the other hand, in cold backward springs such as 1969, seed maggots, *Hylemya platura* (Meigen), and seed corn beetles, *Agonoderus lecontei* Chaudoir, and *Clivina impressifrons* LeConte, cause damage which the growers blame on poor germination of the seed. Seed maggots usually damage corn that has not been treated properly with an insecticide (or untreated). Control of seed corn beetles is more difficult but, fortunately, these insects appear only at long, irregular intervals.

Cole Crops

Western Ontario grows about 75% of the cole crops in the province, of which the largest plantings are in Kent and Essex counties. The cabbageworm complex causes the greatest damage, and these insects are found in all parts of the province. Adequate controls are available for the imported cabbageworm, *Pieris rapae* (Linnaeus), and the diamondback moth, *Plutella maculipennis* (Curtis), but in recent years the cabbage looper, *Trichoplusia ni* (Hübner), has become a serious problem on cole crops. Very few growers practice a complete protection program. Consequently, if earlier stages of the cabbage looper are allowed to develop, it is more difficult to kill worms in the later instars. These insects seem to be almost immune to many insecticides. *Bacillus thuringiensis* destroys the larger loopers but the process takes a long time, although feeding is slowed up considerably. In 1970 a number of growers in Kent County programmed their spraying operations. The results were excellent, but the costs were high.

In the Guelph and Toronto areas the cabbage maggot, *Hylemya brassicae* (Bouché), is considered the most serious pest of cole crops in the province.

Peas

Seventy percent of the 20,000 acres of peas is grown in southwestern Ontario. Only the pea aphid, *Acrythosiphon pisum* (Harris), causes any appreciable damage and control measures seem to be well in hand. If proper seed treatments are used, seed maggots and wireworms cause little trouble.

Beans

Some 3,000 acres in Ontario are given over to growing beans as vegetables. Lima beans are grown on about one-quarter of this acreage. Toronto, Burlington and Kent districts produce more than one-third of the bean crop; elsewhere the crop is widely scattered. White beans, grown for the pork and bean industry, are regarded as a field crop and are not considered here. Insects are not serious pests in string beans most seasons. Occasionally, seed maggots and the potato leafhopper, *Empoasca fabae* (Harris), cause damage. In 1969, however, the bean aphid, *Aphis fabae* Scopoli, was very destructive to

lima beans in Kent County, in late July and early August. In many instances, only the prompt application of an aphicide saved the crop.

The Mexican bean beetle, *Epilachna varivestis* Mulsant, causes some damage to string beans; it is more prevalent near Lake Huron than elsewhere in the province. It frequently causes severe damage to white beans grown in this area, but it is only of local occurrence.

Seed maggots and the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), may cause damage to garden beans but it is rarely serious. Controls for these pests are considered adequate.

Spinach

Toronto, Burlington, and Kent are the chief areas for spinach, of which some 600 acres are grown in Ontario. The cabbage looper is the most important pest and appears to be more significant in Kent County than elsewhere. The spinach leaf miner, *Pegomya hyoscyami* (Panzer), causes little damage most years. Occasional pests are various species of cutworms, the fall armyworm, the celery leaf tier, *Udea rubigalis* (Guenée), and the seed corn maggot. In 1969 the beet armyworm, *Spodoptera exigua* (Hübner), was found in scattered areas at Erieau. This was the first record of its appearance, in the field, in Ontario. It was recorded from a number of greenhouses in southwestern Ontario, and it is thought to have entered the province on chrysanthemum cuttings imported from Georgia.

Processing firms are dissatisfied with the present recommendations for looper control in spinach. This is not a serious pest but the product must be in perfect shape, and free of insect fragments, for canning. This product is widely used in processed baby foods. *Bacillus thuringiensis* gives good control.

Asparagus

The asparagus acreage is widely scattered in Ontario, with the greatest concentrations in the Kent-Essex and the Georgian Bay areas. However, there are indications that the growing of asparagus is being curtailed near Collingwood. Several minor pests, such as the pigweed casebearer, *Coleophora amaranthella* Braun, are sometimes found on this crop. The only important pests are the asparagus beetle, *Crioceris asparagi* (Linnaeus), and the spotted asparagus beetle, *Crioceris duodecimpunctata* (Linnaeus). Present controls are considered adequate, if begun early in the season.

Potatoes

Although a vegetable, potatoes are usually classified as a field crop because of the large acreage grown. About two-thirds of the nearly 50,000 acres grown in the province are found west of Toronto. Fully a third of the total acreage is grown in the counties of Simcoe and Dufferin.

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is found in all areas but is not as serious a pest as formerly. Modern insecticides keep this insect well in check, and present control recommendations are deemed adequate. If a regular spray program is followed, the potato leafhopper and the potato flea beetle are well controlled. The tarnished plant bug, however, is a growing problem in the main potato-growing area. Some extension workers feel that this insect warrants more extensive study. Of particular concern is its possible role as a vector of virus diseases.

The potato aphid, *Macrosiphum euphorbiae* (Thomas), is generally regarded as the most important pest of potatoes in Ontario. Growers are dissatisfied with current control methods, and are apprehensive about the spread of disease by aphids. It is felt that further research is needed on this species.

The chief soil pests of potatoes in the province are seed maggots, wireworms and white grubs. Formerly, wireworms (several species) were very serious pests and caused great damage. White grubs, *Phyllophaga* spp., also did considerable damage but were generally easier to cope with than wireworms. There is some apprehension that, with the withdrawal of the so-called "hard" hydrocarbon insecticides from the market, there

might be an increase in damage by both these species of insects. Reports of wireworm damage in various crops are becoming more frequent.

Peppers

Nearly two-thirds of the pepper crop is grown in Essex County, but there is increased production in both the Burlington and Norfolk county areas. More than 1,000 acres of sweet peppers are grown in the province. The second-generation European corn borer has been a serious problem in peppers in and around Harrow, but more recently it has spread wherever peppers are grown in Ontario. Adequate control is costly, and growers are dissatisfied with current recommendations. The borer not only enters the pepper fruit but it allows admission of the soft rot organism, *Erwinia caratovora* (Jones) Holland. The green peach aphid, *Myzus persicae* (Sulzer), was formerly a serious pest of peppers and transmitted the virus disease known as tobacco etch. More recently aphids have been of less concern. The pepper maggot, *Zonosemata electa* (Say), seems to be largely confined to Essex County where it is associated with its wild host, the horse nettle, *Solanum carolinense L.* When this plant is kept under control the maggot is not an important pest. Foott and Timmins (1970) have recently published a review of pepper insects in southwestern Ontario.

Cucumbers

Cucumbers are largely grown in Kent-Essex, Toronto, and Norfolk. Generally, the striped cucumber beetle, *Acalymma vittata* (Fabricius), remains the prime pest. However, at Burlington, the spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber, causes the greatest damage. Frequently as many as 10 sprays are needed to keep this insect in check, and growers are disturbed, as this increases production costs. The melon aphid, *Aphis gossypii* Glover, and the squash bug, *Anasa tristis* (De Geer) are pests of local importance that may cause serious damage if not checked.

Seed maggots may cause serious injury in cold, wet seasons, but the presently-recommended seed dressings are very effective in controlling these pests. The squash vine borer, *Melittia cucurbitae* (Harris), and the onion thrips, *Thrips tabaci* Lindeman, are frequent pests of cucurbit crops.

Beets

Red beets are mainly confined to the muck soils of Bradford and the Kent-Essex areas. Some 900 acres are grown in Ontario. Leaf miners and flea beetles cause minor damage, particularly to bunching beets, but insects are seldom important in this crop.

Onions

Onions are divided into dry onions and bunching or fresh market onions. Over 2,000 acres of dry onions, about 60% of the crop, are grown in the Bradford marsh. The Kent-Essex marshes produce some 25% of the crop. Bunching onions are grown mainly in the Toronto, Kent-Essex, Burlington and Niagara regions.

The onion maggot, *Hylemya antiqua* (Meigen), remains the most important pest, especially in a wet season. Control against this insect is costly and opinion as to the adequacy of the controls used is divided. According to McEwen *et al.* (1970), some of the newer materials offer excellent promise for maggot control when used in granular form. In bunching onions, thrips cause severe damage in dry years. Very poor control is obtained with present recommendations, and the grayish-green appearance of the leaves affects the sale of the product. Occasionally, cutworms cause severe damage to onions, but they are of local concern, and appear at periodic intervals.

Rutabagas (Turnips)

Rutabagas, for the most part, are grown in the Guelph and London districts, with sizable acreages near Burlington and Toronto. The chief pests are the seed maggots,

Hylemya floralis (Fallén), and *Hylemya brassicae* (Bouché). These insects can cause serious losses from shortly after seeding until the plants are half grown. Despite a carefully followed program that has been developed to counteract damage, some areas are more prone to damage than others. The crucifer flea beetle, *Phyllotreta cruciferae* (Goeze), and the striped flea beetle, *Phyllotreta striolata* (Fabricius), may burrow into the developing root, thus reducing the sale of the rutabagas. To control them the grower must be alert before the beetles are established. Also, the turnip aphid, *Hyadaphis psuedobrassicae* (Davis), may cause serious losses if left unchecked. Cabbageworms, loopers, and the zebra caterpillar, *Ceramica picta* (Harris), sometimes attack the foliage of rutabagas.

Radish

One-third of the radish crop in Ontario is grown in the Toronto area, with the remainder widely distributed over the province. The same insects that attack rutabagas feed on radishes. The control program seems to be well in hand since this crop matures quickly.

Carrots

Nearly 60% of the carrot acreage is located in the Bradford area; the rest of the 4,000 acres is scattered throughout the province. London and Toronto districts have fair-sized acreages. Although the aster leafhopper, *Macrosteles fascifrons* (Stål), and the carrot rust fly, *Psila rosae* (Fabricius), remain problems, the growers for the most part seem to be fairly well satisfied with current control recommendations. Control of the aster leafhopper is maintained by weed control along field edges. When the weedy areas are reduced or eliminated, the leafhopper causes little damage.

The carrot weevil, *Listronotus oregonensis* (LeConte), is confined to a very limited area of the Bradford marsh and at Thedford. It is not important so far. Nematodes were cited as a problem in carrots at Thedford. The possible increase of wireworms, because of the withdrawal of hydrocarbon insecticides, is causing concern to some processors.

Lettuce

Bradford grows about 60% of the lettuce produced in the province. The aster leafhopper is the chief pest. According to the growers, the recommended control is adequate but impractical. A number of other species of insects also attack lettuce, but are generally considered minor pests. Among these are aphids, cutworms, and wireworms. Slugs can be a nuisance in some areas.

Celery

Celery is another crop that is grown principally in the Bradford marsh, with smaller acreages in Essex-Kent, London, and Burlington. The aster leafhopper is the most important pest. It is difficult to control in this crop and growers are dissatisfied with the recommendations. The cabbage looper frequently causes serious damage to celery, particularly in the Erieau marsh. So far there has been no satisfactory control in celery, although several of the newer insecticides offer promise. The bacterium, *Bacillus thuringiensis,* gives excellent control but the mummified bodies of the loopers are left on the plants over a long period. Also, the treatment cost is very high. The tarnished plant bug is sometimes a serious problem in the Burlington area and present control recommendations are inadequate.

Minor Crops

Several hundred acres are given over to growing relatively minor crops. Included here are the cucurbit plants—pumpkin, squash, and melons. Aphids and the striped cucumber beetle may attack all these plants. The squash bug, *Anasa tristis* (De Geer), sometimes severely damages pumpkins and squash, while the squash vine borer, *Melittia cucurbitae* (Harris), can completely destroy stands of some species of squash.

Table II. Insects known to damage vegetables in southern Ontario

Crop and pest	Yearly occurrence	Regional status	Economic status
ASPARAGUS			
Asparagus beetle	annual	general	A
Spotted asparagus beetle	annual	general	B
Pigweed casebearer	variable	local	C
Asparagus miner	variable	local	C
Cutworms	variable	local	B
BEAN (Snap, Lima and Pole)			
Cutworms	variable	general	B
Wireworms	variable	general	C
Seed maggots	annual	general	B
Mexican bean beetle	annual	adjacent to Lake Huron	B
Green cloverworm	variable	local	C
Aphids	variable	local	C
Flea beetles	variable	local	C
Bean thrips	variable	local	C
Potato leafhopper	annual	general	A
Two-spotted mite	variable	local	C
BEET			
Aphids	variable	local	C
Leaf miner	variable	local	C
Cutworms	variable	local	B
Wireworms	variable	local	C
Flea beetles	annual	local	C
CARROT AND PARSNIP			
Root aphid	variable	local	C
Carrot rust fly	annual	general	A
Six-spotted leafhopper	variable	local	C
Carrot weevil	annual	Bradford marsh	C
Carrot swallowtail	variable	very local	C
Wireworms	formerly common		
Nematodes	unknown		
CELERY			
Six-spotted leafhopper	annual	local	A
Tarnished plant bug	annual	local	A
Cabbage looper	variable	local	B
Carrot rust fly	variable	local	C
Aphids	variable	local	C
Celery leaf tier	variable	local	C
Cutworms	variable	local	C
COLE CROPS			
Root maggot	annual	general	A
Cabbageworm	annual	general	A
Cabbage looper	annual	general	A
Diamondback moth	annual	general	B
Zebra caterpillar	variable	local	C
Cabbage aphids	annual	local	B
Flea beetle	annual	general	A
Cutworms	variable	local	B
Wireworms	variable	local	B
Thrips	variable	very local	A
CORN			
European corn borer	every year	general	B
Corn earworm	intermittent	variable	B
Corn leaf aphid	every year	general	B
Chinch bug	variable	Essex County	C

Sap feeding beetle	variable	general	C
Wireworms spp.	variable	general	B
Corn rootworm	regularly–last 10 years	continuous corn area	A
		rotation	C
Cutworms spp.	variable	general	A
Root maggot	every year	general	C
Armyworm	variable	local; sometimes general	B
White grubs	variable	local	A
Billbugs	variable	local	C
Seed corn beetle	variable	local	C
Slender corn beetle	variable	local	C
Grasshoppers	variable	very local	C
Corn flea beetle	seldom	local	C
Cereal leaf beetle	unknown	unknown	C
Fall armyworm	variable	local	C
Slugs	variable	local	C
CUCURBIT			
Striped cucumber beetle	annual	general	A
Spotted cucumber beetle	annual	general	B
Squash bug	annual	local	C
Squash vine borer	variable	local	C
Aphids	variable	local	B
Thrips	variable	very local	C
Two-spotted spider mite	variable	very local	C
Seed-corn maggot	variable	local	B
Cutworms	variable	local	C
Wireworms	variable	local	C
Pickleworm	very variable	very local	C
Leafhoppers	variable	very local	C
LETTUCE			
Six-spotted leafhopper	annual	general	A
Aphids	variable	local	B
Cabbage looper	variable	local	B
Cutworms	variable	local	C
Slugs	variable	local	C
ONION			
Onion maggot	annual	general	A
Thrips	annual	general	A
Cutworms	variable	local	B
PEA			
Pea aphid	annual	general	A
Seed maggot	annual	general	B
Pea weevil	variable	very local	C
Cutworms	variable	local	C
PEPPER			
European corn borer	annual	general	A
Pepper maggot	annual	local–Essex County	B
Aphids	annual	local	B
Cutworms	variable	local	C
POTATO			
Colorado potato beetle	annual	general	A
Potato flea beetle	annual	general	B

Potato leafhopper	annual	general	A
Aphids	variable	local	A
Wireworms	variable	local	B
White grubs	variable	local	B
Tarnished plant bug	variable	local	A
Seed-corn maggot	variable	local	B
Blister beetle	variable	mainly northern area	B
Potato scab gnat	variable	very local	C
Stalk borers	variable	very local	C
European corn borer	variable	very local	C
Millipedes	variable	local	C
Black cutworm	variable	Alliston area	C
SPINACH			
Spinach leaf miner	annual	general	B
Aphids	variable	local	B
Cabbage looper	variable	local	C
Beet armyworm	reported only in 1969	Erieau	C
TOMATO			
Tomato hornworm	variable	local	B
Flea beetles	annual	general	B
Aphids	variable	very local	C
Cutworms	variable	local	C
Wireworms	variable	local	C
Crickets	variable	Essex County	A
Tomato fruitworm	very variable	very local	C
Tomato russet mite	very variable	very local	C
Drosophila sp.	variable	general	C
Sap beetle	annual	Kent-Essex	A
Colorado potato beetle	variable	Kent-Essex	C
RUTABAGAS			
Root maggots	annual	general	A
Flea beetles	annual	local	A
Aphids	annual	general	A
Zebra caterpillar	variable	local	C
Cabbageworm complex	variable	local	C

A – Insects that are generally present every year and are a constant threat
B – Insects that are variable in their appearance, but may cause serious damage locally
C – Of minor importance

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II. INVITATION PAPERS

AN ANALYTICAL CHEMIST'S CONTRIBUTION TO APPLIED ENTOMOLOGY[1]

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Abstract

The role of an analytical chemist as a member of a pesticide research team in applied entomology is described. Available methods and relevant discussion concerning spray application and its assessment are exemplified. Attention is drawn to the association between biological activity and chemical residue data to show the persistence of pesticides in conjunction with the term "half-life". The advantage of individual leaf analysis for deposits is illustrated in order to establish a relationship between mortality data of insects or mites and minimum effective deposits.

Introduction

In recent years, the importance of teamwork – cooperative research by a multidisciplinary group of scientists – has been frequently discussed by many establishments, including government, university and industry. In Canada some research establishments have initiated this team approach, whereas others are still in the planning stage.

The pesticide research group of the Research Station, Canada Department of Agriculture, Vineland Station, has been practicing cooperative research for the past three years. Our pesticide research program is complicated and involves many activities, such as toxicological study, improvement of sprayers, efficacy and persistence of pesticides in the laboratory and field, interactions of pesticides, and residue analysis including the analysis for degradation products. The purpose of these studies is to find cheaper, safer and more effective pesticides, more precise and safer methods for their application, and to transmit this information to the horticultural industry of Ontario.

To solve these complex problems effectively, the cooperation of scientists of many disciplines is essential. Our team consists of two entomologists, one acarologist, one plant pathologist and myself, an analytical chemist. Recently, an agricultural engineer joined the team to strengthen the engineering aspects of our research. Naturally, each scientist has a defined responsibility in the teamwork; the role of the chemist is to develop analytical methods for the detection and quantitation of pesticides under specific conditions and carry out analyses to help interpret data from the activities of other team members.

This paper summarizes the usual activities of an analytical chemist, or more specifically of a pesticide-residue chemist, and gives some highlights of my three-year's research work in applied entomology.

Analytical Methods Employed by an Analytical Chemist

Generally in our research, one complete analytical procedure is divided into three major steps: extraction, cleanup and determination. Materials to be analyzed at Vineland vary widely, but fruit, soils, leaves, insects, and different kinds of test papers are handled frequently.

Of the many determination techniques, gas chromatography is the most widely

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used and most sensitive method for many pesticides. It is an essential tool in any residue laboratory. Thin-layer chromatography is frequently used for purification, screening, and semi-quantitative determination. Colorimetric methods are still important because some pesticides cannot be identified by gas chromatographic methods. Of the modern techniques, liquid scintillation is unique and used with radioactive compounds. Mass spectrometry is relatively new and becoming popular, particularly in conjunction with gas chromatography.

The analytical techniques employed are usually the personal choice of the chemist. Since the type of analysis required in our research is different from ordinary residue analyses, standard bulk analysis methods are not suitable. For this reason, several new rapid methods have been developed to meet our specific requirements.

Practical Application of Analytical Methods

In practice, we can apply these methods in a team approach in numerous ways, but I would like to discuss three major objectives which are closely associated with our pesticide research program at Vineland.

Spray application. The first objective is to improve pesticide spray application techniques. Until we find other practical and effective pest control methods, the use of pesticides must be continued in order to maintain the current level of agricultural production. Many different kinds of sprayers are used for pesticide application; the gun-type sprayer is still used but so-called air-blast sprayers have become dominant in recent years.

Regardless of the sprayer used, its performance is influenced by the number and size of nozzles, pressures, concentration of pesticides, driving speed, tree size and shape, foliage density, and tree spacing. Even under ideal conditions, variation in distribution of spray deposits, both in droplet size and amount of chemicals, is noticeable, and biological efficacy varies accordingly. For example, one study showed that variation of carbaryl spray deposits determined by a rapid, individual leaf analysis method (Chiba, to be published) on peach trees with a gun-type sprayer using carbaryl wettable powder was significant. Deposits on leaves from the tops, bottom inside, and bottom outside of trees varied widely within and between the areas. If ordinary bulk analyses were made, only three average figures would have been obtained, but the data from individual analyses indicated that average figures would have been misleading, because the average figures were greatly influenced by a few exceptionally high deposits (Chiba, to be published).

The rapid method developed by me to evaluate carbaryl spray deposits or residues on leaves is unique. Up to 250 individual leaves can be analyzed in a day, whereas only 8 bulk samples may be analyzed by the AOAC official method. Because the new method does not require sophisticated instruments, it can be used in the orchard to check the performance of sprayers, and the effects on deposits of a rain soon after spraying.

Three sprayers were compared in vineyards, using the same amount of chemicals but at different concentrations. The high-volume, hydraulic sprayer performed much better than the low-volume air-blast sprayer when judged by the following four criteria: uniformity of spray deposit, amounts of chemical deposits, and mite and powdery mildew control (Chiba, Fisher, Northover, Herne, and Neff, to be published).

The performance of eight different types of sprayers was compared in an apple orchard, using the same amount of chemicals under the best operating conditions for each sprayer. Their performance was judged according to spray coverage of foliage and by carbaryl deposits. Results obtained are interesting, because the sprayer which gave the most uniform coverage gave the least amount of deposit. By contrast the sprayer that deposited the greatest amount of chemical was rated only fourth in the coverage rating (Chiba and Fisher, to be published).

From an efficacy viewpoint, uniform coverage has been considered to be more important than the amount of chemicals. In the past, therefore, our effort was concentrated on the improvement of efficacy. However, efficacy is no longer the sole factor. Nowadays, we must also consider environmental pollution caused by pesticide spray applications. For example, if one sprayer gives less than half of the amount of

deposit obtained by another sprayer when using the same amount of chemicals, we must ask, where does the remaining 50% of the material go? To investigate this question, we conducted a season-long experiment in 1970, to find out what sort of spray conditions would give the most uniform coverage with the greatest amount of chemical deposit and the least amount of environmental pollution. The results will be discussed in detail elsewhere.

Laboratory and field experiments. The second objective is to conduct laboratory and field experiments and assess their importance in relation to spray application problems. The experiments include a toxicological study to establish the minimum effective doses necessary to kill insects or mites and relate this to spray deposits, a study of relative persistence and behavior of insecticides and acaricides after application, and tests of the toxicity of degradation products.

One of these studies was a trial to relate mortality of the adult female European red mite to dicofol spray deposits on peach trees. The average spray deposit was much greater in a 13.4 kg/ha (12 lb/a) plot than it was in a 6.7 kg/ha (6 lb/a) plot as expected, but the mean mortality was less with the former than with the latter. If the ordinary bulk analyses had been made in this case, this contradictory result could not be elucidated. However, with individual leaf analyses, the poorer average mortality in the 13.4 kg/ha plot was found to be due to a small number of leaves which received exceptionally low deposits, and the low mortalities on these leaves caused the lower average (Herne and Chiba, to be published).

One of the highlights of this experiment was the finding of the minimum effective deposits on foliage to give 100% mite kill. The mite mortality declined rapidly regardless of the original amounts of deposits, but the residues determined by chemical analysis decreased more slowly. As a result, seven days after the application, the same amounts of deposits gave much less mite mortality.

The analytical method employed in this experiment is a rapid gas chromatographic method which was developed by myself in cooperation with Dr. D. C. Herne of the Vineland Research Station. With this method, an analysis is made of the same piece of sample used for the mite mortality test so that a direct relationship between the mortality and deposits should be obtained (Chiba and Herne, to be published).

Persistence of pesticides. The third objective concerns the real meaning of "persistence" of pesticides. From the results in the foregoing paragraph, I must question the validity of general residue analysis used routinely to assess the persistence of pesticides. If a chemical stays on the sprayed target without decomposing, but in several days becomes less effective against insects or mites than when applied, then chemical residue data are misleading. In my opinion, the persistence of chemicals must be judged not only by chemical analysis, but also by biological activity.

"Biological availability" is the key term applied to measure a chemical's biological activity at the target site. It is well discussed with soil insecticides (Harris, 1966) and with soil extracts (Chiba, *et al.,* 1970). The discrepancy between the mite mortality and residue data which I have discussed in the preceding paragraph probably resulted from physical change in deposits or penetration of dicofol into cuticles, where it became unavailable to the mites but was extracted by the solvent (Herne and Chiba, to be published).

The term "half-life" is often used when discussing persistence of pesticides, and dicofol has a relatively long half-life compared with several other pesticides. However, we already know that the half-life of dicofol in a general sense has no direct relationship to its biological activity.

The most common misunderstanding of half-life occurs in connection with DDT. The half-life of DDT is often quoted as 15 years or more. This is true in soil, but not true when DDT is in or on other media. The half-life of DDT on plants is a maximum of 55 days (Gunther and Blinn, 1955). Concerning environmental pollution, however, this type of half-life data is not meaningful, because even when DDT disappears from the soil by evaporation or leaching, or from sprayed plants by evaporation, as long as it stays as original DDT the total amount of DDT in our environment would not change at all.

I studied the rate of decomposition of DDT to DDE (Chiba, 1970), because DDE is known to be practically nontoxic. Though recently DDE was incriminated in the thinning of eggshells of certain species of birds, (Hickey and Anderson, 1968), the overall significance of this decomposition product in the environment is much less than that of DDT. By my calculation, the half-life of DDT in decomposing to DDE on grapevines was less than one year. In soil it could be longer than 15 years and a similar calculation could be made for other media, such as in air or water, but very little is known to date.

Conclusions

I hope that the contribution of an analytical chemist to applied entomology is evident from this discussion.

The standard bulk analysis which requires a large sample is often acceptable, but I have shown that to obtain a relationship between mortality data regarding mites or insects in orchards and spray deposits, an analysis must be made of the same sample used for the mortality test. I have also shown that increasing the amount of chemicals in order to improve biological efficacy is of little value unless spray techniques are improved.

The areas in which an analytical chemist can contribute are unlimited. More extensive work is required to find the most effective droplet size and the minimum effective dose of many insecticides. The minimum effective dose of insecticides against different stages of insects will form a nucleus for further research and practical application. This study is exceptionally important because if successful, the minimum amounts of the most suitable insecticides can be applied at the weakest point in an insect's life cycle. This is a wiser use of insecticides in conjunction with the utilization of ecological and biological knowledge. This integrated control is the best method for controlling insects without creating environmental catastrophes. Obviously, an analytical chemist can contribute significantly to the accomplishment of this formidable task as a member of the cooperative research team.

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CONTROL OF CABBAGE INSECTS BY VIRUSES

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Abstract

Natural epizootics of the nuclear-polyhedrosis virus of the cabbage looper, *Trichoplusia ni* (Hübner), (*T. ni* NPV) and the granulosis virus of the imported cabbageworm, *Pieris rapae* (Linnaeus), (*P. rapae* GV), contributed substantially to control of the host insects in non-treated plots of cabbage in the latter part of the growing season. When applied to plants in plot tests, the viruses controlled the respective host insects as well as or better than did chemical insecticides. A combination of *T. ni* NPV with a chemical insecticide was among the most effective treatments.

T. ni NPV and *P. rapae* GV produced in natural epizootics of the diseases accumulated in soil and on foliage in non-treated plots and fields. Residues of the respective viruses were found in 60 and 19% of samples of soil taken from 116 fields in Ontario in which cole crops were grown commercially. Residues in soil in plots increased with repeated natural epizootics and after three years apparently initiated epizootics of disease in host populations sufficiently early to protect the crop. Residues of *T. ni* NPV and *P. rapae* GV in soil and on plants at harvest in non-treated plots were similar to residues in plots to which the viruses were applied earlier in the season.

Advantages of viruses over chemicals as insecticides are discussed. Features of viruses include: safety for man, domestic animals and wildlife; no direct effect on populations of insects and mites that parasitize or prey upon pest insects; no pollution of environment because viruses are naturally occurring; inability of insects to become resistant to viruses; and economy of viruses because of efficacy and long-term effect on pest populations.

The usefulness of viruses in control of insect pests has been known for some time (Steinhaus, 1954). Most entomologists are aware that viruses occurring naturally are important in natural control of several insect pests of crops and forests, and it is commonly known that some viruses are highly effective control agents when applied as insecticides. Viruses of the two principal pests of crucifers in Ontario, the cabbage looper, *Trichoplusia ni* (Hübner), and the imported cabbageworm, *Pieris rapae* (Linnaeus), are among the most effective viruses in both natural and applied control (Hall, 1963; Ignoffo, 1968a). The virus of *T. ni* is of particular interest as an applied insecticide because of the difficulty in killing medium- and large-sized *T. ni* larvae with chemical insecticides.

Description of the Viruses

Larvae of *T. ni* are susceptible to three, or possibly four, different viruses (Jaques, 1970a) but the virus that is of interest as a bioinsecticide is the nuclear-polyhedrosis virus (NPV) that occurs most commonly. The important virus of *P. rapae* is a granulosis virus (GV).

Nuclear-polyhedrosis virus diseases are characterized by development of multisided proteinaceous crystalline intracellular inclusion bodies (polyhedral bodies) formed in the nuclei of cells in susceptible host tissues. The polyhedral inclusion bodies of the nuclear-polyhedrosis virus of *T. ni* (*T. ni* NPV) are 3 to 5 μ in diameter and are easily seen with a dark-field or phase contrast light microscope. Each contains 50 to 100 or more virions (virus particles).

The intracellular inclusion bodies (granules) of the granulosis viruses are oblong in shape and much smaller than polyhedral inclusion bodies. Granules of the granulosis virus of *P. rapae* (*P. rapae* GV) measure about 0.2 by 0.3 μ and are seen as minute dots with the light microscope. Each granule contains only one virion.

The virions of nuclear-polyhedrosis and granulosis viruses are rod-shaped, about 50 by 280 mμ. They contain DNA.

The NPV and GV viruses usually kill the host in the larval stage but virus infections initiated in larvae may kill pupae. Larvae are extensively decomposed when killed by these viruses and often are found hanging by the abdominal prolegs. Diseased larvae may be recognized before death by a characteristic yellow color, sluggishness and failure to feed. The body wall of cabbage loopers becomes slightly transluscent and the abdomen is distended near death by NPV. This feature is not as noticeable with *P. rapae* GV disease. Shortly after death the cadavers of the insects are essentially sacs of virus-laden liquid. This liquid is released with rupture of the body wall, thus contaminating foliage of the plant or the soil. Healthy larvae eating the contaminated foliage are infected and killed and in this way the disease is spread through populations.

Insect viruses, especially NPV and GV types, are highly specific, usually killing only insects of one species or of closely related species (Ignoffo, 1968b). For example, *T. ni* NPV infects *T. ni* larvae but not *P. rapae* larvae whereas *P. rapae* GV infects *P. rapae* larvae but not *T. ni.*

Natural Occurrence of Diseases and Viruses

Natural epizootics of virus diseases kill large proportions of populations of *T. ni* and *P. rapae.* Studies begun at Harrow in 1967 have shown that populations of *T. ni* reach a peak early in September. Two weeks later few healthy larvae can be found in non-treated plots, largely due to the high incidence of *T. ni* NPV (Jaques, 1970; Jaques, unpublished). Epizootics of *P. rapae* GV cause equally dramatic reductions in populations of *P. rapae.* Harcourt (1966) has demonstrated that *P. rapae* GV is the key mortality factor regulating populations of *P. rapae* in the Ottawa area. Unfortunately natural epizootics of viral diseases decimate populations of *P. rapae* and *T. ni* only after the crop has been damaged extensively. Therefore virus usually must be introduced artificially into the population to initiate an epizootic early in the season if crop protection is to be achieved.

Residues of *T. ni* NPV and *P. rapae* GV are common in the environment, particularly where epizootics of the diseases have occurred. The virus released on the death of the host insect is usually smeared on the foliage where it may be eaten by a healthy larva, thus infecting it. Virus on foliage is inactivated within a few days if exposed to sunlight (Jaques, 1967a) but unexposed deposits may remain active for long periods. Cadavers of virus-killed insects may drop to the ground, or residues on foliage may be incorporated into the soil when the leaf falls to the ground. In the soil the virus is protected from ultraviolet radiation and persists for long periods. The virus in soil contaminates foliage by being splashed onto the plant by rainfall or is deposited with soil on foliage during cultivation.

It has been shown that the *T. ni* NPV remains active for long periods in soil (Jaques, 1964, 1967b). *T. ni* NPV applied to soil in small field plots retained over 30% of its original activity six years after application (Jaques, 1969b). The virus is not leached from the soil, but remains near the surface of uncultivated soil (Jaques, 1969a) and readily contaminates plants grown there. Preliminary tests (Jaques, 1970b; Jaques, unpublished) indicate that *P. rapae* GV also persists in soil. David and Gardiner (1967) showed that the GV of *Pieris brassicae* an insect closely related to *P. rapae,* remained active for at least two years in soil.

Because viruses persist in soil, residues accumulate from year to year in fields in which populations of host insects have been killed by them. A survey that included 116 samples from fields in 14 counties of Ontario in 1968 and 1969 showed that viruses of *T. ni* and *P. rapae* were widespread in soil in fields in which crucifers were grown (Jaques and Harcourt, 1971). *T. ni* was found in 68 and 45% of samples taken in the respective years. The granulosis virus of *P. rapae* was less common, being found in 18 and 19% of the samples. Because these fields were not treated with a virus, it is concluded that the residues of the viruses in soil resulted from virus produced when larvae were killed by naturally occurring diseases.

Studies on plots at Harrow demonstrated accumulation of viruses of *T. ni* on foliage and in soil from natural epizootics of the disease in host populations in two successive

years (Jaques, 1970a, 1970b). Three viruses of *T. ni* occurred in soil, a typical NPV, an atypical NPV, and a granulosis. The typical NPV was the most common virus. The study showed that residues of the three viruses in soil were related qualitatively and quantitatively to residues on leaves of cabbage grown in the plots and to mortality by the viruses in host populations. In 1970 residues of typical NPV in soil and on foliage in the non-treated plots near harvest were similar to residues in plots treated with high concentrations of virus earlier in the season (Table I). It is significant that substantial residues of viruses were found in plots sprayed with Thiodan or Thuricide, apparently due to natural occurrence of disease in host larvae that survived the insecticide treatment. Similar observations on natural occurrence of *P. rapae* GV have been made. The high residues of the viruses in non-treated plots demonstrate the widespread natural occurrence of the virus and indicate the safety of the virus when applied as an insecticide. Also, the quantitative and qualitative relationship of residues in soil and on foliage suggest the role of soil as a source of virus to initiate epizootics of virus in populations of the host one or more seasons later. Contamination of foliage of cabbage plants by virus in soil was demonstrated in earlier studies (Jaques, 1967b).

Table 1. Residues of nuclear-polyhedrosis virus of *Trichoplusia ni* and granulosis virus of *Pieris rapae* in soil and on foliage in plots at Harrow

Treatment of plot		Percentage of test larvae killed by virus in bioassay test[a]			
		Foliage		Soil	
Material	Application[b]	*T. ni*	*P. rapae*	*T. ni*	*P. rapae*
Check 1967-70		54	21	78	57
Check 1968-70		82	31	88	41
Check 1970		71	23	43	45
T. ni + *P. rapae* viruses	4 foliar	64	15	96	25
T. ni + *P. rapae* viruses	1 soil	92	18	100	50
Thiodan[c]	4 foliar	85	20	90	6
Thuricide[c]	4 foliar	100	17	79	19

[a]Data are for samples of foliage and soil taken on October 6 and October 15, 1970, respectively.

[b]Rates of application of virus are listed in Table III.

[c]Thiodan 4EC and Thuricide 90TS are formulations of endosulfan and *Bacillus thuringiensis* respectively

One objective of the author's research is to determine whether sufficient virus will accumulate naturally in soil to protect the crop or at least reduce damage to the crop. Damage to plants in non-treated plots planted to cabbage only in 1970 was greater than damage to plants in non-treated plots planted to cabbage in four consecutive seasons (1967-1970) (Table II). This indicates that peak numbers of *T. ni* larvae were reduced apparently by mortality by virus accumulated from repeated epizootics.

Table II. Damage by insects to foliage of late cabbage plants grown in 1970 in non-treated check plots cropped to cabbage for varying numbers of consecutive years

Years cropped to cabbage	Numbers of feeding holes
1967, 1968, 1969, 1970	226
1968, 1969, 1970	248
1970	434

Application of Viruses for Control of *T. ni* and *P. rapae*

Tests by several workers (Hall, 1963; Fox and Jaques, 1966; Genung, 1960; Jaques, 1970b; McEwen and Hervey, 1958; Tanada, 1956) have demonstrated that *T. ni* NPV and *P. rapae* GV, especially the former, are highly effective insecticides when applied to cole crops to control the respective host insects. However, until recently, widespread use of the viruses was at best a remote possibility because of several obstacles.

Figure 1. Damage by insects to late cabbage in a non-treated check plot (upper photograph) and in a plot sprayed four times in 1970 with the nuclear-polyhedrosis virus of *Trichoplusia ni* (2.5 x 10^{12} polyhedra/acre) and the granulosis virus of *Pieris rapae* (4.9 x 10^{12} granules/acre) (lower photograph).

First, stable forms of the viruses have been reproduced only in insect tissue. Thus mass production of the viruses was not possible until recent development of methods to produce massive numbers of host larvae (Ignoffo, 1968).

Second, satisfactory methods for production and standardization of pure products of viruses and for detection and identification of the viruses and their residues were required.

The third obstacle, registration to permit sale of a commercial product, is proving to be more difficult than was first expected. For example, a virus recently registered for use against the cotton bollworm, *Heliothis zea,* a serious pest of cotton in the United States, was probably tested more extensively than any other insecticide proposed for registration in the past 10 years. This caution is understandable because viruses are not only new insecticide materials but their use represents a whole new concept in insect control.

The virus of the cabbage looper is now being considered for registration. The virus of the cabbageworm is somewhat further back in development. It is nearly as effective an insecticide as the looper virus, but the cabbageworm has been more difficult to rear and therefore less research has been done on the disease. Also, the cabbageworm can be controlled readily with chemicals. On the other hand, larvae of the cabbage looper, when half-grown, are extremely difficult, if not impossible, to control with chemical insecticides. The doses of such highly toxic insecticides as methomyl and endosulfan required to give even moderate control are excessively high and expensive. Since large *T. ni* larvae can be safely and economically controlled by *T. ni* NPV, the virus is considered to have potential as an alternative to chemicals for control of *T. ni* on cole crops.

Plot tests at Harrow in 1967, 1968, 1969 and 1970 have demonstrated the value of viruses for control of *T. ni* and *P. rapae* (Jaques, 1969c, 1970b). In plot tests in 1970 (Jaques, unpublished), viruses, chemical insecticides and formulations of *Bacillus thuringiensis* were applied to foliage of late cabbage on four occasions (July 30, August 10, August 20, and September 2). The viruses were applied once (July 30) to soil in some plots. The control effected by the treatments is illustrated by photographs of representative cabbage plants from two of the plots (Figure 1). Numbers of medium and large-sized larvae on plants on August 28 and September 16 demonstrated that *P. rapae* was of minor importance near harvest, whereas *T. ni* was a very significant pest in some plots (Table III). Foliar application of *T. ni* NPV reduced numbers further than did applications of endosulfan or Thuricide 90TS, a formulation of *B. thuringiensis.* A combination of Thiodan and *T. ni* virus was also effective. One application of the viruses to soil early in the season appeared to give good late-season control of *T. ni.* The protection of the crop

Table III. Numbers of medium and large larvae of *Trichoplusia ni* and *Pieris rapae* on cabbage plants near harvest and foliage damage in plots treated with viruses and other insecticides in 1970

Treatment of plot			Larvae/10 plants				Numbers of feeding holes/10 plants
			August 28		Sept. 16		
Material[a]	Applications[b]	Rate /acre	*T. ni*	*P. rapae*	*T. ni*	*P. rapae*	
Check	–		127	10	54	2	434
Thuricide 90TS	4 foliar	2 qt	75	0	57	2	99
Thiodan 4EC	4 foliar	1.5 pt	94	0	72	2	208
T. ni + *P. rapae* viruses	4 foliar	[c]	23	1	24	0	102
T. ni + *P. rapae* viruses	1 soil	[c]	91	7	20	7	119
T. ni virus + Thiodan 4EC	4 foliar	0.5 pt[c]	52	0	48	4	130

[a]Thuricide 90TS is a registered formulation containing the bacterium *Bacillus thuringiensis* as the active ingredient. Thiodan 4EC is a formulation of endosulfan.

[b]Foliage was sprayed on July 30, August 10, August 20, and September 2; soil was sprayed on July 30.

[c]2.5×10^{12} *T. ni* NPV polyhedral bodies or 4.9×10^{12} *P. rapae* GV granules were applied/acre to foliage in each application. The soil application contained 1.25×10^{13} *T. ni* NPV polyhedral bodies and 2.45×10^{13} *P. rapae* GV granules/acre. When applied with Thiodan, 2.5×10^{11} *T. ni* NPV polyhedra bodies and 0.5 pt of Thiodan were applied/acre.

by the treatments, estimated by the numbers of feeding holes in foliage of plants at harvest, shows that control effected by the *T. ni* NPV and *P. rapae* GV equalled or surpassed that by other materials (Table III).

Three growers applied *T. ni* NPV to parts of fields of late cabbage with conventional spray equipment in 1970. The virus was applied five to seven times between July 22 and September 19 at the same times as chemical insecticides were applied to the remainder of the fields. Numbers of medium and large larvae of *T. ni* on plants in the fields show that the control effected by the viruses was equal or superior to that of chemical insecticides (Table IV). One grower used an excessive amount of methomyl (Lannate) (1 lb/a, double the recommended rate) and obtained slightly better control than by the virus. Applications of methomyl and a formulation of *B. thuringiensis* (Thuricide 90TS) by the other two growers did not control *T. ni* as well as did the virus, especially late in the season.

Table IV. Numbers of medium and large larvae of *Trichoplusia ni* on late cabbage in parts of growers' fields sprayed 5 to 7 times with *Trichoplusia ni* nuclear-polyhedrosis virus and other insecticides in 1970

Grower	Treatment[a]	Numbers/30 plants			
		Aug 15	Aug 27	Sept 17	Oct 1
Grower No. 1	Lannate	26	6	28	20
	Virus	128	45	21	45
Grower No. 2	Lannate + Thuricide	18	21	18	150
	Virus	8	84	5	8
Grower No. 3	Lannate + Thuricide	8	24	48	204
	Virus	42	21	23	75

[a]Lannate and Thuricide 90TS are formulations of methomyl and *Bacillus thuringiensis* respectively. Rates/acre/application were: Lannate, 1/2-1 lb; Thuricide, 2 qt (Imp); *T. ni* virus, 5.7×10^{12} polyhedral bodies.

Features of Viruses as Insecticides

Studies to date have demonstrated that the viruses of *T. ni* and *P. rapae* are highly effective when applied as insecticides for control of their host insects. In addition to being equally or, as is *T. ni* NPV, more effective than chemicals for control of *T. ni* and *P. rapae* on cole crops, the viruses have several advantages over chemicals as insecticides.

Safety. The insect viruses are considered to be harmless to man, domestic animals, wildlife, and crops. There has been no evidence that insect viruses have any effect when fed to warm-blooded animals and, therefore, they can be used safely on a crop immediately before harvest. Because the viruses occur naturally on most cole crops, humans undoubtedly have been exposed to the virus for many years with no ill effects attributed to the virus.

Selectivity. The viruses do not kill beneficial insects, the parasites and predators, that aid in insect pest control. The well-informed entomologist or ecologist today realizes that regardless of how effective these natural agents are, applications of insecticides will continue to be needed to control some insects at acceptable levels. The use of insecticides can be minimized, however, by efficient use of the natural agents. The efficient combination of natural and applied agents is termed "integrated control", and is the goal of much of the pest control research in Canada today.

The viruses are ideal for use in integrated control because they affect only the target pest species. For example, the viruses of the looper and cabbageworm do not kill ladybugs or larvae of the Syrphid fly that eat aphids on cabbage. Furthermore, they do not kill birds that eat large numbers of the larvae.

Non-polluting. The viruses of *T. ni* and *P. rapae* occur naturally in the environment and therefore their use adds nothing new or foreign to the soil or crop. Substantial

residues of the viruses occur naturally on foliage or in soil in plots not sprayed with virus. At harvest, such natural residues may equal or exceed residues on plants sprayed with virus earlier in the season. Therefore it is apparent that application of the virus merely builds up a residue earlier in the season than would have occurred naturally.

No insect resistance. Repeated exposure of insects to viruses in laboratory tests indicate that it is very unlikely that insects could develop resistance to viruses.

Economical. Viruses are economical because one or two applications may give acceptable control throughout the season. This would represent a considerable saving for the grower, particularly in labor.

Summary

It is quite apparent that viruses have a very real potential for control of insects on cole crops, especially the cabbage looper. The use of the viruses alone or in combination with chemicals and insecticides containing the bacterium *Bacillus thuringiensis* in a program to control insects on cabbage is very promising.

The advantages in the use of microbial insecticides are quite apparent. With pollution being the largest problem facing us in the 1970's, the lack of pollution from viruses used for insect control may lead to their extensive use sooner than anticipated.

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III. SUBMITTED PAPERS

PROBLEMS ASSOCIATED WITH SPRAYING LARGE TREES IN ONTARIO APPLE ORCHARDS[1]

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Abstract

With the use of tables and illustrations of sprayers, a description is given of the difficulties associated with spraying large apple trees in Ontario orchards. Air velocity from an air-blast sprayer decreased from 150 mph at the outlet to 30 at 10 feet and 16 at 20 feet. When the sprayer moved at 4.5 mph, the air velocity was 16 mph at 10 feet and 0 at 20 feet. The dense side canopy cut the air speed from 30 to 5 mph when the sprayer moved forward at 3 mph. Poor coverage inside the tree caused increases in populations of red mites, woolly aphids, and scale insects. Coverage ratings increased as the output volume and/or air volume was increased.

The 1966 apple tree census showed 3,135 orchards in Ontario, of which 75% were standard size and 25% semi-dwarf and dwarf; the proportions have not changed greatly since then. It is obvious, therefore, that the apple orchards of Ontario present highly variable targets for spray application. Because about 25 models of sprayers, varying in size from 10 to 120 horsepower, are in use in Ontario apple orchards, the problem of matching sprayer and tree size is formidable. In addition, variations such as orchard acreage, land type and configuration, and weather and pest stress affect sprayer suitability.

Current Status

A large apple tree is an ever-changing target throughout the growing season as bare limbs and twigs become clothed with flowers and leaves, and as the developing fruits gradually bend the flexible limbs. Small trees, with stiff central leaders and limbs, remain upright and open and permit better light and spray penetration than do large trees. Dwarf trees have almost 60,000 square feet more leaf surface per acre than do standard trees (Heinecke, 1968), and produce higher yields of fruit with better color, and are easier to prune, spray, and harvest.

Large trees are those on standard rootstocks spaced from 35 to 40 feet apart. These trees occupy a very small part of the available space for the first 10 years but, when mature, almost touch in the row, and are from 6 to 8 feet apart between rows. Because young standard trees present a small target, several top nozzles on the sprayer must be closed and the spray started and stopped at each tree (Figure 1). Because of the wide spacing, the spray stream must travel a long distance before reaching the foliage (Figure 2). If veering winds are blowing, accuracy in hitting the target is low.

With "high volume" output (200 to 600 gal/acre), the weight of water ensures contact with the tree even against moderate breezes. However, when "low volume" sprays (15 to 75 gal/acre) are projected, the water weight is not adequate and even in a high velocity air stream, the smaller droplets may be turned aside by wind and miss the target entirely.

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[1]Contribution No. 196

Mature standard trees may be 18 to 22 feet high and the foliage is close to the sprayer. All nozzles on the sprayer are kept open and the spray angle is much wider. Spray enters the tree almost immediately and wind interferes much less with spray direction when the leaves are fully opened and the tree still upright (Figure 3). However, during the dormant to bloom period, even light winds can pass easily through the bare limbs and turn a spray back before it reaches the midpoint of the tree (Figure 4a). Later, when fruit hangs heavily on the trees, the ends of the limbs are depressed, and mat-like shingles on the lower outside portions form a dense barrier to both air movement and spray penetration (Figure 4b). This barrier is clearly demonstrated by the reduction in air velocity behind the skirt portion of the canopy (Table 1).

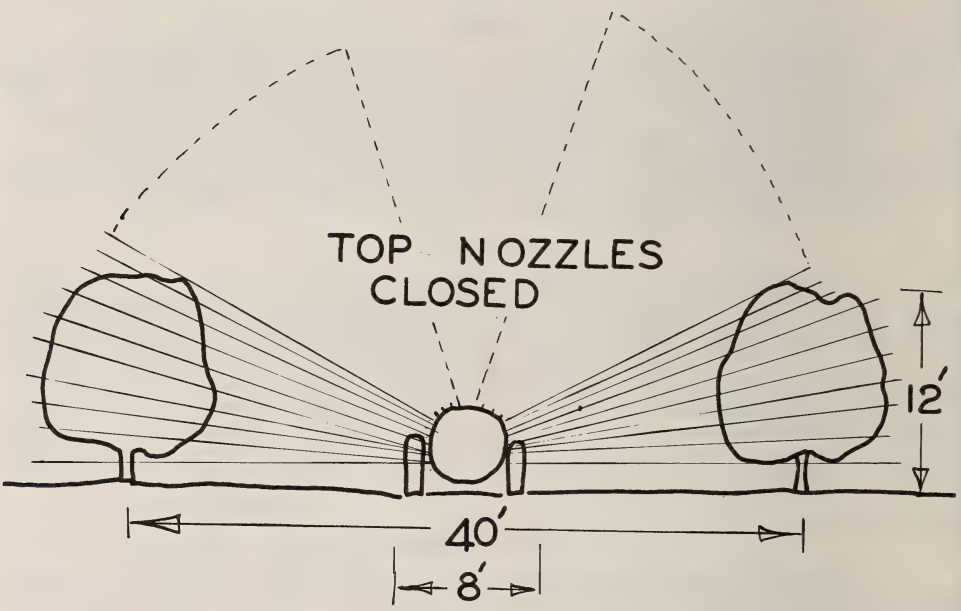

Figure 1. Small standard trees on wide-row spacing require only half of the spray pattern.

Table 1. Decrease in air velocity with distance from a sprayer emitting about 40,000 cu ft of air per minute. Large standard trees. Clarksburg, Ontario, August 1970

Driving speed of sprayer	Horizontal maximum velocity between trees in mph at the following distances (ft)							
	0	5	10	15	20	25	30	35
Standing	150	60	30	20	16	9	6	4
2 mph		45	24	12	8			
4.5 mph		24	16	8.5	0			
	Within the trees							
1 mph			8*			12**		3***
3 mph			5*			11**		0***

* inside the canopy, ** bottom center, *** tree top

The consequence of this lack of penetration is shown in Figure 5 and Table 2. The top branches of large standard trees are most often under-sprayed. The reasons are several: (1) the tree is too tall and air velocity too low to make droplets impinge (Table 3); (2) skirt areas are too dense to allow spray to penetrate to the tops; (3) the sprayer

travels too fast to allow spray to penetrate the canopy; (4) wind stops the spray before it reaches the top; (5) lanes between rows are closing and overhanging branches interrupt spray emission; and (6) droplets are too small or too few in number.

Table 2. Relationship between coverage of foliage in different parts of the tree by a miticide, and control of European red mite. Simcoe, Ontario, 1968

Location in tree	Percent of leaves with poor coverage rating	Number of mites per 50 leaves
Top inside	8	51
Bottom inside	30	331
Skirt inside	27	230
Skirt outside	22	85

The undersides of leaves in the tree top receive spray material only as it travels upward; however, the upper surfaces get repeated coatings as the mist settles downward from several directions. The coverage rating for undersides is, therefore, more accurate when comparing efficiencies of different sprayers. Further, coverage is increased by an increase in liquid output and air displacement (Table 3).

Table 3. Relationship of nozzle size, output volume, and air volume to coverage ratings * in tree tops. Clarksburg, Ontario, August, 1969

Number of nozzles	Swirl plate number**	No. of air streams	Gallons per acre	Coverage rating
5	23	1	17.5	290
5	23	2	17.5	324
10	23	2	35	482
5	25	1	33.5	369
5	25	2	33.5	404
10	25	2	67	546

* rating of coverage on upper plus lower surfaces of 20 leaves per tree, 3 replicates, in the top inside part of the tree, using the fluorescent dye tracer Phosphor 2283, and a rating range of 1 to 10

** Spraying Systems Co. 3201 Randolph St. Bellwood, Illinois. No. 23 has 2 openings of 2/64"; No. 25 has 2 openings of 4/64".

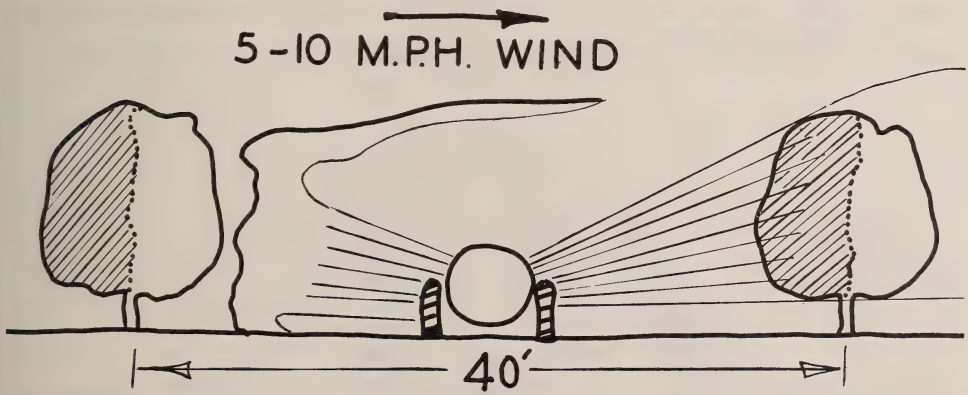

Figure 2. Small standard trees on wide-row spacing. Note that only half the tree is adequately sprayed because of wind interference.

In a survey in 1969 and 1970 to evaluate efficiency of sprayer use in Ontario orchards, Fisher and Hikichi (1971 unpublished) found that semi-dwarf and dwarf trees could be satisfactorily sprayed with all sprayers, even when the sprayers were not in proper adjustment; large trees were difficult to spray well, and the inadequate coverage greatly reduced pest control. When an oil spray was not used in early spring because of

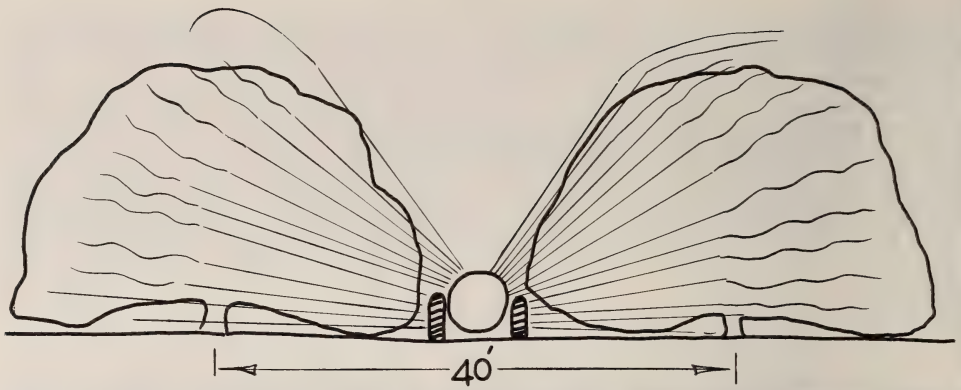

Figure 3. Mature standard trees require the full spray pattern. Wind has less effect when foliage is close to sprayer.

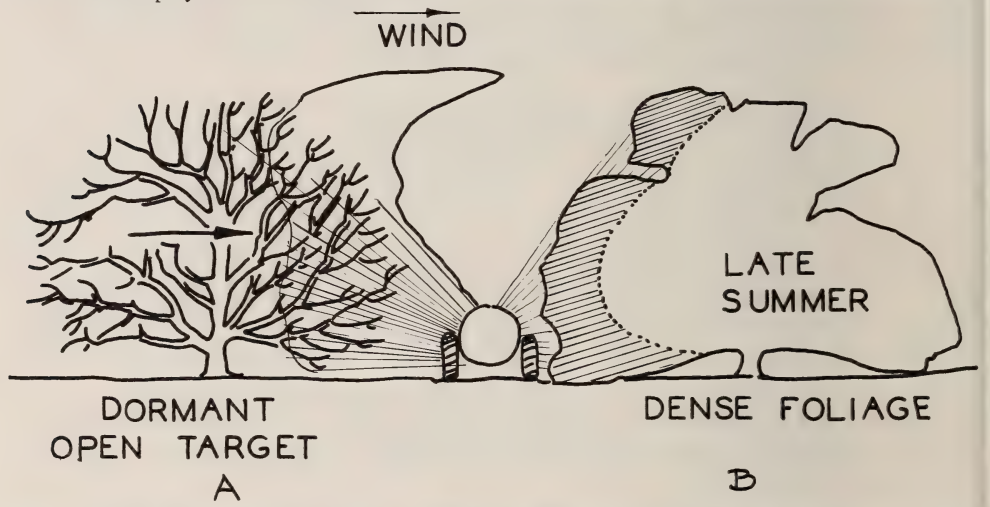

Figure 4a. Open framework of a dormant tree allows wind to pass through and stop the spray before it reaches the tree center.

Figure 4b. Dense outer canopy catches most of the spray and leaves the interior poorly covered.

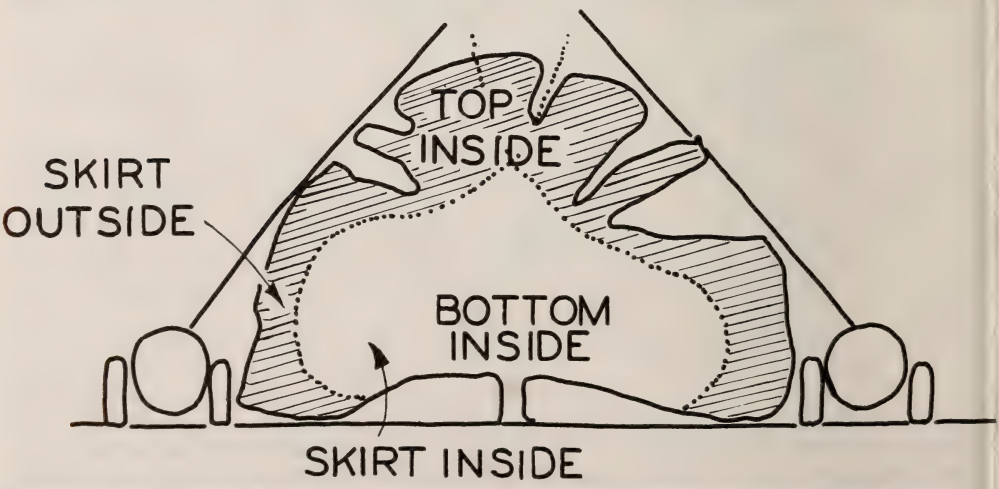

Figure 5. As in 4, showing the poorly covered center even when the tree is sprayed from both sides.

wet ground or windy conditions, poor coverage of bark brought a resurgence of San Jose, European, and oystershell scales, and woolly aphids. Poor coverage on leaves in tree tops and interiors allowed red mite and apple scab to develop out of control.

When large and small trees occurred together, extra effort was needed to close nozzles in top and bottom positions for small trees. The small targets and wide gaps presented by young standard trees allowed excessive spray to be blown over and around them and thus wasted. Large trees were hard to prune and to open up for good fruit color and spray penetration, and were awkward and slow to harvest.

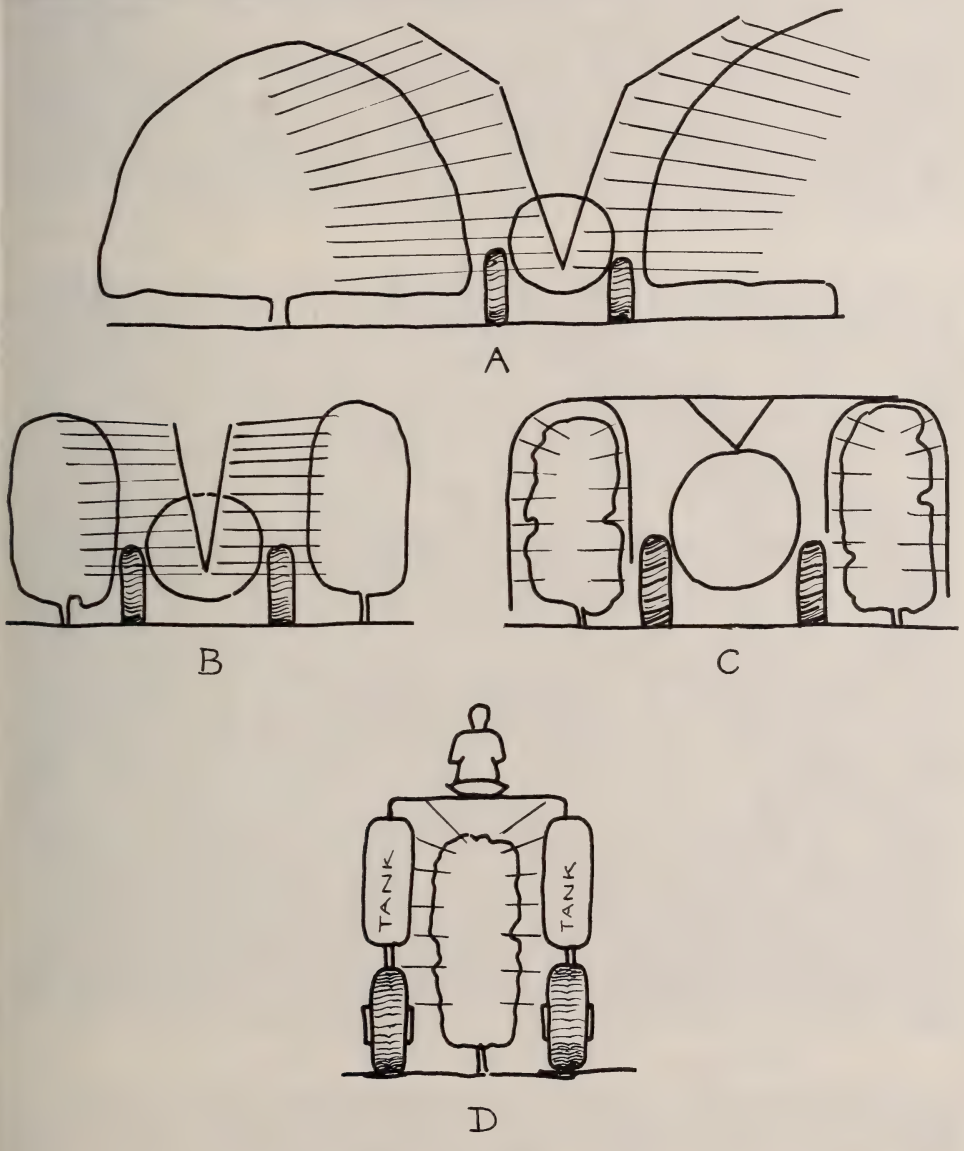

Figure 6a. Suggested air-assisted spray boom directing spray horizontally to reduce drift.
Figure 6b. Air-assisted boom sprayer directing spray horizontally into grape vines or apple tree walls.
Figure 6c. Hooded air-assisted sprayer for tree walls.
Figure 6d. Self-contained hooded sprayer for one row; this could be extended laterally using hooded spray units (as in c) to cover several rows at a time.

Future Trends

Changes in the concept of fruit tree size and style of orchard plantings are taking place rapidly, and as these are put into practice the design of sprayers will have to change. Loss of spray chemicals to the atmosphere occurs by volatilization from foliage but also from misdirected sprays. The higher cost of large equipment and the long waiting period between planting time and profitable production both dictate a change to high density plantings of small trees. To follow the changing tree form, sprayers will have to be of different design. For those able to retain their plantings of large trees for some years yet, an air applicator with movable twin stacks to direct spray horizontally into the foliage from close range would be feasible (Figure 6a). The small air-blast sprayer now in use for semi-dwarf and dwarf trees could be changed in a similar way to reduce waste and drift (Figure 6b). Successful use of hoods on hydraulic and air-shear sprayers in grapes (Figure 6c) suggests that a much cleaner, cheaper spraying job can be done with hooded air sprayers on small trees and tree walls. "High-boy", self-propelled air sprayers for single or multiple row orchards are a logical progression for the future (Figure 6d).

Acknowledgments

The author is indebted to G. P. Dougan for technical assistance with experimentation and analysis of data.

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FORTY YEARS OF BAIT TRAPPING THE ORIENTAL FRUIT MOTH, *GRAPHOLITHA MOLESTA* (BUSCK) (LEPIDOPTERA : TORTRICIDAE), ON THE NIAGARA PENINSULA, ONTARIO[1]

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Abstract

The oriental fruit moth, *Grapholitha molesta* (Busck), was trapped in a number of peach orchards on the Niagara Peninsula, from 1927 to 1938 and from 1948 to 1969. During the first period a molasses solution was used as bait in the traps and during the second, a much more attractive terpinyl-acetate, brown sugar bait was used. The trapping records indicate that over much of the time the fruit moth has been in the area it has been held to relatively low numbers. Records of fruit injury from 1926 to 1961 generally fluctuated in the same way as the bait trap records, and indicate that the outbreak of the moth in the late 1940's developed over a three-year period.

Introduction and Methods

Bait trapping of the oriental fruit moth was started in a peach orchard in the St. Davids area of the Niagara Peninsula in 1927, about two years after the fruit moth was first detected in Ontario. Records of numbers of moths caught in bait traps in various

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[1] Contribution No. 198

[2] Retired, October 1970

peach orchards were kept for each generation of the moth till 1938, when trapping was discontinued because the moth had been reduced to such low numbers that it was no longer considered a serious threat to the peach-growing industry.

A great increase in injury by the fruit moth in 1945 in several orchards along Lake Ontario, where it had previously caused little damage, and a more general outbreak in 1947 and 1948, revived interest in the moth and bait trapping was resumed in 1948 in several orchards. The resumption of trapping coincided with the first widespread use of DDT to control the moth and it has been continued for the purpose of timing spray applications.

The records of bait trapping back to 1927 were examined to see whether trends in moth numbers could be detected during the 34 years such records were kept. The trapping records were extracted from unpublished annual reports of the Vineland Research Station, Canada Department of Agriculture, Vineland Station, Ontario. The data recorded herein are taken largely from reports by G. G. Dustan and some from those of W. L. Putman. The number of traps used each year varied from 90 in 1928 to 10 in 1937 and 1938. Usually 10 traps, placed in that part consisting of the cultivar Elberta, were used per orchard.

Figure 1. Type of bait trap used to capture the oriental fruit moth from 1948 to 1969

Unfortunately, no bait-trap records were available for the years 1938 to 1948, when the most recent severe outbreak of the moth developed. In an attempt to bridge this gap, data relating to fruit injury from 1926 to 1961 were extracted from the reports of the Vineland Station laboratory and plotted with the bait-trapping records.

From 1927 to 1938 a bait consisting of molasses and water was used in the traps. Since 1948, a brown-sugar-terpinyl-acetate bait has been used (Chisholm *et al.*, 1946). The type of trap used varied somewhat over the years in which the records were made, but usually consisted of a glass or metal container of about one-quart capacity, screened

with ½-inch mesh hardware cloth and suspended from a tree limb (Figure 1). Dustan (1961) stated that in a comparative test the terpinyl-acetate-baited traps caught 33 times as many moths as molasses-baited traps. Though this reported difference probably does not indicate the relative effectiveness of the two baits when used independently, still, the records before 1948 are probably not on the same scale as those taken later.

The use of organochlorine and organophosphorus insecticides for fruit moth control began to come into widespread use in Ontario peach orchards about 1948. It was possible, therefore, to divide the bait-trap records after 1948 between sprayed and unsprayed orchards. However, in many years only one unsprayed orchard (10 traps) was represented in the bait-trap records because of the widespread use of the above insecticides, while records from 3 to 7 sprayed orchards were usually reported. The numbers of fruit moths caught in traps was often highly variable between orchards.

Results and Discussion

The percentage fruit injury of the late cultivar Elberta fluctuated in a similar way to the yearly averages of moths caught in bait traps in those years when comparable data were available (Figure 2), suggesting that the bait traps do reflect real changes in the fruit moth population levels. The records of percentage fruit injury for the years when no bait trapping was done indicate that fruit moth numbers remained low till about 1942 when there was a more or less steady increase to 1947. The rapid decline in percentage fruit injury following 1948 closely paralleled the decline in numbers of moths caught in the bait traps.

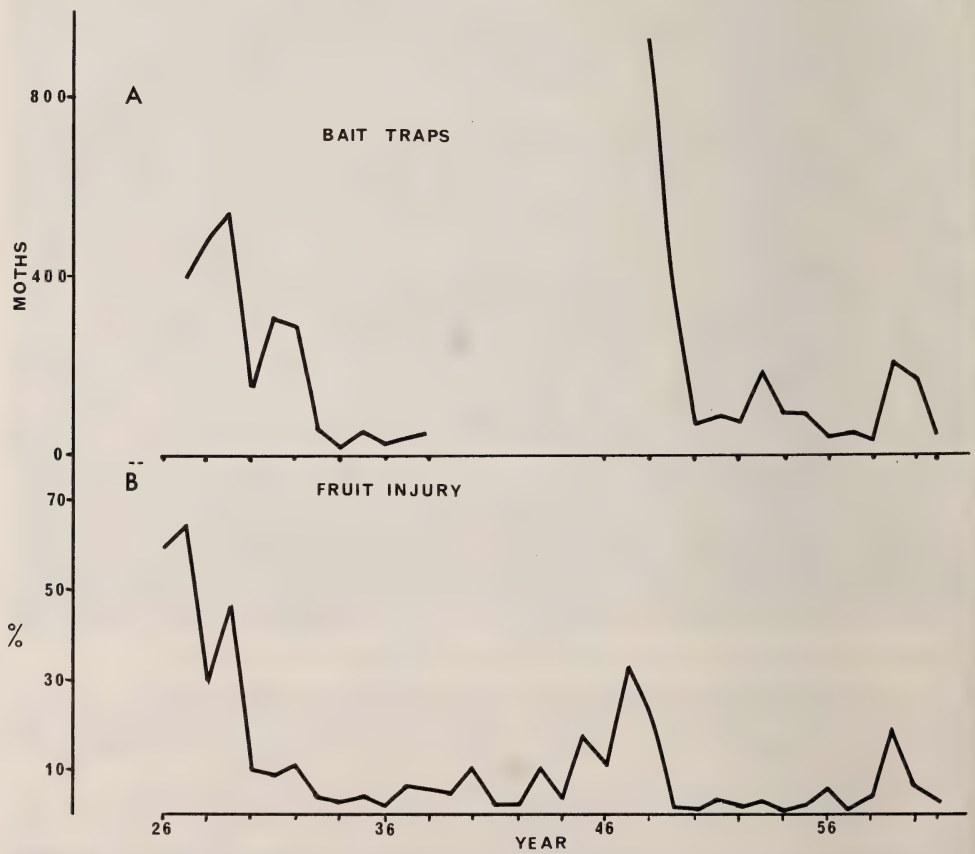

Figure 2. A. Average numbers of oriental fruit moths caught per bait trap per year. B. Percentage of fruit injured by the oriental fruit moth on the peach cultivar Elberta per year.

The bait-trap records plotted on an arithmetic scale (Figure 3A) show that moth numbers declined from a high level in 1927 to a low point about 1933 and remained at a relatively low level till 1938. When bait trapping was resumed in 1948, the numbers of moths were again very high but declined rapidly so that by 1950 they were at a low level. Since 1950 the numbers of moths caught have fluctuated around a relatively low mean, except for upsurges in 1959 and 1962.

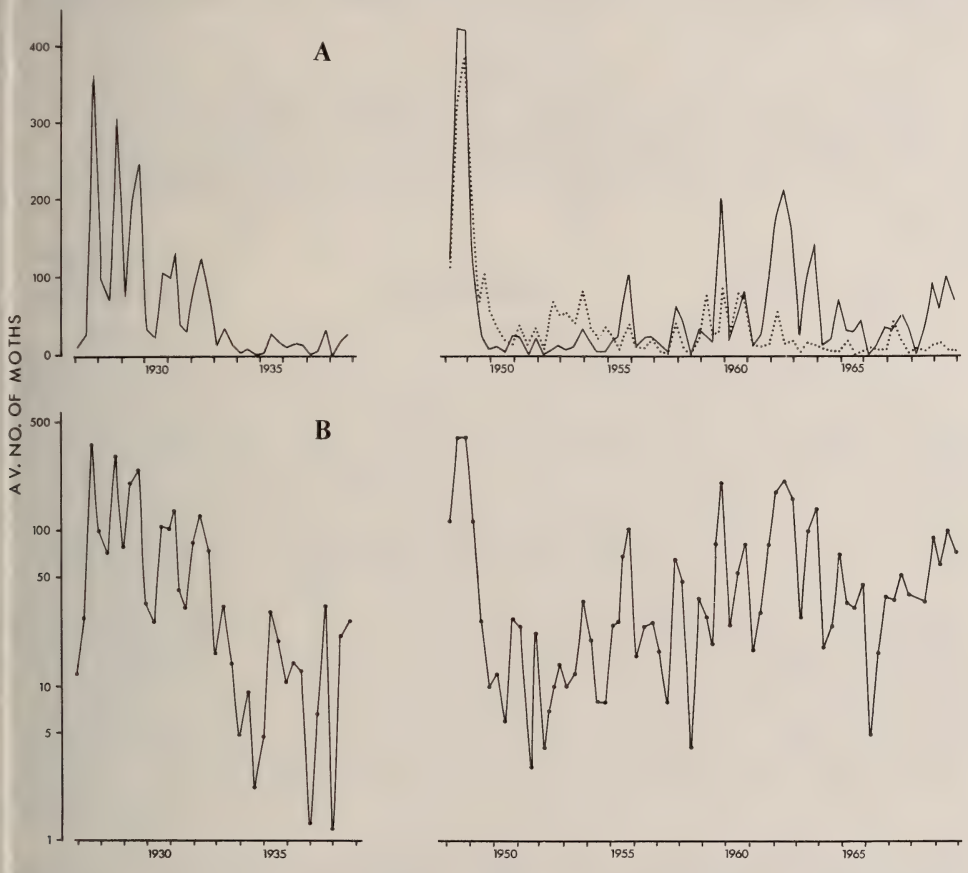

Figure 3. A. Average numbers of oriental fruit moths captured per bait trap in successive generations plotted on an arithmetic scale. B. The same data plotted on a logarithmic scale.

The data from sprayed orchards give a very similar pattern to those from unsprayed. In fact, after the outbreak in 1948, the numbers of moths appear to have fallen somewhat lower in the unsprayed orchards than in the sprayed ones. After about 1959, the mean number of moths caught in the sprayed orchards appears to be lower than in the unsprayed, but the difference may not be significant.

It is noticeable that fluctuations of the logarithms of numbers of moths caught in bait traps are of the same order at all population levels, suggesting that population outbreaks are not caused by an unusually great rate of increase in any one generation (Figure 3B). The numbers of moths rarely showed more than a 10-fold increase or decrease between successive generations.

Allen and Plasket (1958) stated that, in general, the numbers of moths in any generation appear to be unrelated to the numbers in the generation immediately preceding it. To determine if this were true on the Niagara Peninsula, the logarithms of the numbers of moths caught in bait traps in each generation were plotted against those

of the preceding generation (Figure 4). In orchards regularly sprayed with insecticides, only the correlation between log numbers of moths caught in the second generation and in the spring generation from 1948 to 1966 was significant at the 5% level. In one unsprayed orchard in which records were taken continuously from 1960 to 1967, there was a highly significant correlation between log numbers of moths caught in the spring generation and in the first generation, but no significant correlation between those in the other generations. These records indicate that correlation between the numbers of moths in succeeding generations may be slight and that mortality in each generation is highly variable.

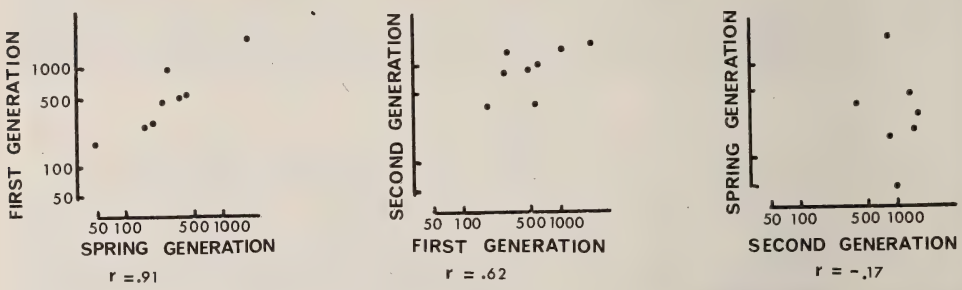

Figure 4. Correlation between log numbers of moths caught in bait traps in successive generations in an unsprayed orchard from 1960 to 1967

The data strongly suggest that over much of the time the fruit moth has been in the Niagara Peninsula, some controlling factors have acted to keep its numbers at a relatively low level. In the late 1940's the moth appears to have escaped the controlling factors and reached outbreak proportions, but by 1950 it was again under control.

So far we have little precise information to explain the factors that are operating to control this pest. Dustan (1961) stated that although outbreaks of the moth coincided with low parasitism in 1942, 1945 and 1948, and declines in moth numbers were accompanied by increased parasitism in 1946, 1949 and 1950, there were other years when the number of moths and amount of fruit injury were high in spite of high larval parasitism. He suggested that weather and condition of the peach twigs and crop may be equally or more important factors in controlling moth numbers, and concluded that parasitism is seldom the chief factor regulating density of the moth. Nevertheless, it is interesting to note that the decline in numbers of the fruit moth following 1929 coincided with the introduction of the parasite *Macrocentrus ancylivorus* (Rohwer) in that year, and the large outbreaks in 1945 and 1948 coincided with low parasitism (Dustan, 1961). More recent studies (Phillips and Proctor, 1970) indicate *M. ancylivorus* may be an important controlling factor in certain years but often other factors cause a greater reduction in moth numbers. Their studies covered only a short period from 1964 to 1967. The data recorded herein suggest that with insects such as the fruit moth, which reach outbreak proportions only at long intervals, short-term studies of the factors governing population levels may be misleading.

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THE OCCURRENCE OF FUNGAL DISEASES OF THE CODLING MOTH IN UNSPRAYED APPLE ORCHARDS IN ONTARIO[1]

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Abstract

Diseases were not important biotic agents affecting the density of overwintering codling moth larvae in southern Ontario. Eleven species of fungi were recovered from field-collected cadavers, the most common being *Beauvaria bassiana* (Bals.) Vuill. and *Isaria* sp. which accounted for 62.5% and 27.7% of the observed mortality respectively. A microsporidian and one spore-forming species of bacteria were also observed in larvae collected in orchards in the Niagara area.

Introduction

Boyce (1941) reported mortality of codling moth larvae due to entomogenous fungi and viral or bacterial organisms in sprayed and unsprayed apple orchards in the Niagara region of Ontario. The specific causal agents involved were not determined, but the author suggested that disease incidence was low and probably of minor importance as a factor affecting codling moth abundance. Later, Garlick and Putman (Putman, 1963), also observed diseased larvae in the same area, but the importance of disease was not systematically assessed. Hikichi (1953) reported the occurrence of *Hirsutella* sp. as well as a bacterium in larvae collected in one commercial orchard in Norfolk County. The fungus was the more prevalent species, and total mortality due to disease in the same orchard was 18.7% in 1953 and 5.3% in 1954 (Hall and Hikichi, 1954).

In Nova Scotia, Pickett and Patterson (1953) and MacLeod (1954), observed *Beauvaria bassiana* (Bals.) Vuill. infesting codling moth larvae. Jaques and MacLellan (1965) subsequently reported that fungal mortality seldom exceeded 10% and averaged 1.7% of the numbers of overwintering larvae in commercial orchards. *B. bassiana* was recovered in 73.1% of the total number of isolates, and together with *Isaria* sp. (7.6%) and *Cephalosporium* sp. (5.7%) accounted for most of the observed mortality. Jaques and MacLellan also found that the incidence of fungal disease was random and not related to population density of the host or to the height above ground level at which the larvae were recovered.

In recent studies (Hagley, 1970), the occurrence of fungal diseases in overwintering codling moth larvae in several localities in Ontario was confirmed. The species present and their relative importance as factors affecting codling moth abundance are herein presented and discussed.

Materials and Methods

The method of removing larval cocoons from the trunks of apple trees, 25 to 40 years old, as well as the unsprayed orchards in which larval numbers were determined, have been previously described (Hagley, 1970). The cadavers collected were placed individually in small gelatin capsules and stored at 4 to 6°C. The causal organisms involved were determined by J. M. Burke, at the Insect Pathology Research Institute, Sault Ste. Marie, Ontario. D. Barber assisted with the collection of cocoons in 1969 and 1970.

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[1]Contribution No. 195

Results and Discussion

In the orchards sampled, codling moth mortality due to fungal diseases averaged 9.8% during the study period (Table 1). The relatively large mortality (16.4%) observed in the fall of 1968 was due primarily to high levels of infection in orchards at Reece's Corner (55.6%) and at Jordan (65.1%) (Hagley, 1970). In these orchards, temperature (>20°C) and relative humidity (85% to 95%) appeared to be favorable for activity of the predominant fungus (Table III) (Schaeffenberg, 1963; Walstad *et al.*, 1970). Under such localized conditions disease may occasionally exert some influence on codling moth survival (see Michelbacher *et al.*, 1950; Russ, 1964), but generally, as mentioned by Boyce (1941) and Hikichi (1952), it is not an important biotic agent affecting abundance in Ontario orchards.

Table 1. Mortality of codling moth larvae due to fungal diseases in southern Ontario

Date	No. trees sampled	No. larvae observed		Percent mortality
		Diseased	Total	
1968				
Spring	97	64	742	8.6
Fall	30	75	459	16.4
1969				
Spring	48	24	277	8.7
Fall	26	23	350	6.6
1970				
Fall	20	27	338	8.0
Totals	221	213	2166	9.8

Table II. The distribution of healthy and diseased codling moth larvae on apple tree trunks[1]

Tree trunk height (ft) above ground level	1	2	3	4	5	6
No. diseased larvae	97	52	18	6	3	0
No. healthy larvae	601	611	288	84	38	10
Total no. larvae	698	663	306	90	41	10

[1]Proportion of diseased larvae on 1st trunk foot greater than that at five other heights (Chi Square = 27.03 significant at 1% level). No significant differences (Chi Square = 5.13, not significant at 5% level) in relative larval numbers on 2nd to 6th foot.

The proportion of diseased larvae on the first foot of tree trunk above ground level was significantly greater than that observed at five other heights (Table II). No significant differences were evident in the relative numbers of diseased larvae occurring at trunk heights between 2 and 6 feet. Jaques and MacLellan (1965) reported that there was no correlation between the incidence of fungal disease and the height (0 to 4 feet) at which the larvae were collected. It was also suggested that disease incidence was random and not related to the density of the larval population. In the orchards sampled by these authors, and in the present study, the number of larvae recovered per trunk foot was probably below the critical level at which a density-dependent relationship would become evident. Further, as suggested by Steinhaus (1954), disease is generally dependent on high host densities for maximum effectiveness, although it occurs at low population levels and is greatly influenced by the weather.

In general the fungi recovered in unsprayed apple orchards in Ontario (Table III) were similar to those found by Jaques and MacLellan (1965) in commercial orchards in Nova Scotia. The most important species present was *B. bassiana*, and together with *Isaria*

Table III. Species of fungi recovered from codling moth cadavers and their distribution in southern Ontario[1]

Fungus Species	No. cadavers recovered at										Total	% mortality
	Bowmanville[2]	Brighton	Essex	Fonthill	Guelph	Jordan	Meaford	Rednersville	Vineland	Vittoria		
A Primary pathogens												
1. *Beauvaria bassiana*	3	4	3	4	6	10	4	1	7	3	45	62.5
2. *Isaria* sp.	–	2	3	7	4	–	–	–	3	1	20	27.7
3. *Cephalosporium* sp.	–	–	1	–	1	–	2	–	–	–	4	5.6
4. *Spicaria* sp.	–	–	–	2	–	–	–	–	–	–	2	2.8
5. *Paecilomyces*	–	–	–	–	–	1	–	–	–	–	1	1.4
B Other species												
6. *Fusarium* sp.	–	–	2	–	1	2	1	–	4	–	10	
7. Yeast	1	–	1	–	–	–	–	–	3	1	6	
8. *Penicillium*	–	–	–	1	–	–	1	–	2	–	4	
9. *Sadasivania* sp.	–	–	1	–	1	–	–	–	–	–	2	
10. *Acrophialophora* sp.	–	–	–	–	–	1	–	–	–	–	1	
11. *Menispora* sp.	–	–	–	–	–	–	–	–	1	–	1	
Totals	4	6	11	14	12	14	8	1	19	5	96	

1 Specific determinations made on material recovered from larvae collected in 1969 and 1970.
Orchard sampled approximately 40 acres in size. Main cultivars were McIntosh, Red Delicious, Baldwin, and Spy.

sp. accounted for 90% of the observed mortality. Only one isolate of *B. bassiana* failed to produce a wine color with the substratum (McLeod, 1954). *Hirsutella* sp. reported by Hikichi (1953) in Norfolk County, and by Jaques and MacLellan (1965) in Nova Scotia, were not recovered from any of the cadavers.

The *Fusarium* sp. and *Penicillium* sp. were probably non-pathogenic, although Madelin (1963) reported that species of these genera sometimes assume some virulence after entering the body cavity of an insect through wounds. *Menispora* sp. and *Sadasivania* sp. are secondary and saprophytic.

One spore-forming species of bacteria (Stephens, 1952) and an undetermined microsporidian were also recovered from larvae taken in orchards at Vineland and Jordan.

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UPWIND ORIENTATION OF FEMALE *SIMULIUM VENUSTUM* SAY (DIPTERA) IN ALGONQUIN PARK, ONTARIO

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Abstract

Collections of flies on all sides of a source of carbon dioxide emission, indicated that females of *Simulium venustum* locate the source by flying upwind. The upwind flight ceases in the absence of this olfactory stimulus. The number of flies caught decreases sharply with the distance downwind from the CO_2 source.

Introduction

Blood-seeking mosquitoes appear to be adapted to respond to the combination of a scent, an air current, and a ground pattern as a means of reaching their host (Kennedy 1939). A similar upwind orientation to a host odor has been suggested for black flies. Lowther and Wood (1964) hypothesized that the host-finding behavior of *Simulium euryadminiculum* Davies involves first the detection of a host-specific airborne scent from the common loon, *Gavia immer* (Brünnich), and then an upwind orientation toward the source of the odor. This olfactory stimulus is derived from the loon's uropygial gland (Fallis and Smith 1964). Smith (1966) emphasized, in addition, the importance of wind in the attraction of *S. euryadminiculum* females. He noted that the flies approached a source of loon's uropygial-gland extract from downwind and maintained a downwind orientation as they hovered near the attractant. Moreover, Smith (1966) suggested that carbon dioxide, considered as a general host-odor, can release an upwind orientation behavior in most simuliids and tabanids. The present paper presents quantitative evidence substantiating the upwind flight response of *Simulium venustum* Say to a wind-borne olfactory stimulus.

Materials and Methods

During the middle and late spring of 1967 and 1968 tests were conducted in Algonquin Park, Ontario, in a large mowed field (auxiliary airfield) where the wind direction remained relatively unidirectional. The apparatus employed in 1967 consisted of a wooden wheel held firmly and horizontally 2 feet above ground, with 16 wooden pegs (each 6 by 1.5 inches) nailed equidistantly around the circumference of the wheel (Figure 1). Down the front and back of each peg a strip of masking tape (4 by 1.5 inches) was applied. The surface of each strip was thinly coated with Bird Tanglefoot (a sticky, transparent substance). The wheel was positioned with pegs Nos. 1 and 16 always facing the prevailing wind direction. A test collection was begun by releasing gaseous CO_2 at a constant rate of 150 cc/min from the center of the wheel when both a moderate breeze and black flies were present. The CO_2 was provided by a compressed gas cylinder through two step-down gauges and a flowmeter. At the end of each test period (of approximately 1 hour), the flies stuck to both strips on each peg were counted and kept in 70% ethanol for later identification. The apparatus was modified in 1968 using a wheel which adjusted its position automatically in response to any small change in wind direction by means of a wind vane (Figure 2). It consisted of a 26-inch bicycle wheel fastened by its axle to a 12-inch circular plywood board held horizontally 3 feet above ground by three aluminum rods bolted on the wooden supporting board. A wind vane was clamped 3 feet above the wheel surface onto a rod held vertically from the center of the wheel by guy wires. Around the circumference of the wheel were clamped 13 wooden dowels over each of which was inverted a glass test tube whose outer surface was coated with a thin layer of

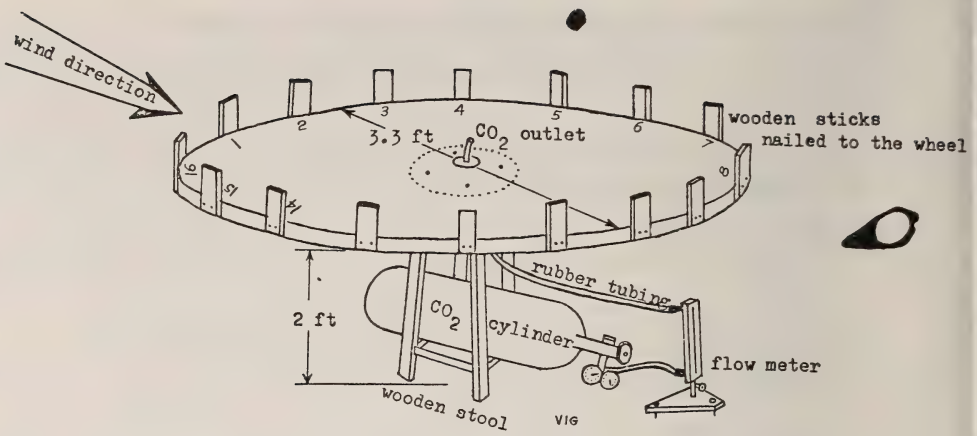


Figure 1. Diagram of the apparatus for studying upwind orientation of female Simuliidae in Algonquin Park, Ontario. Spring 1967.

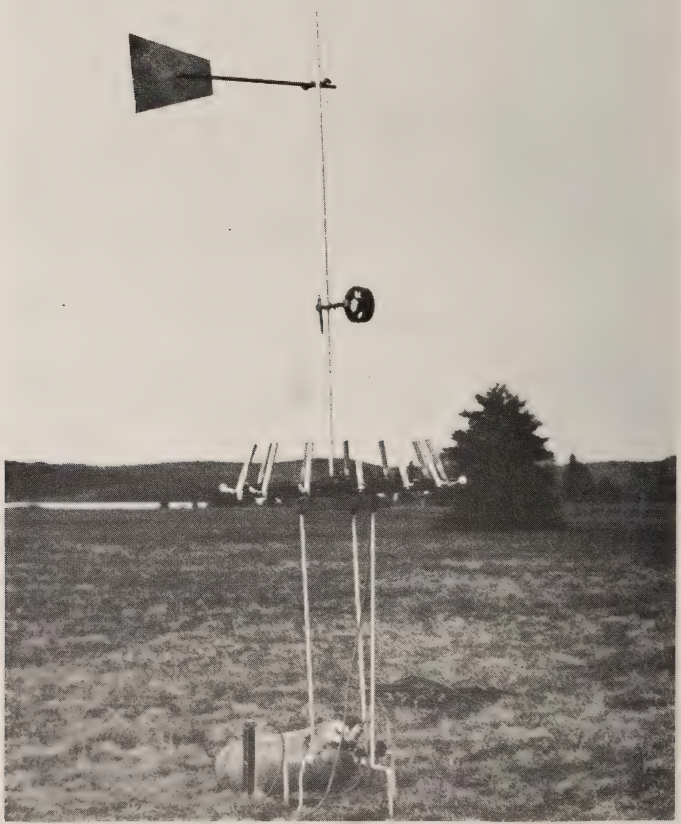


Figure 2. The modified apparatus for studying upwind orientation of simuliids in an open field in Algonquin Park, Ontario. Spring 1968. Sticky inverted test tubes rest over 13 wooden dowels attached to a 26-inch bicycle wheel. Above the wheel are the wind meter and wind vane, while below are the CO_2 gas cylinder and flowmeter.

Bird Tanglefoot. Throughout each collection CO_2 was released at 300 cc/min from the center of the wheel and the wind speed was recorded with a windmeter. A control trap consisting of a similar apparatus, but from which no CO_2 was released, was placed 50 feet from the CO_2 trap on a line at right angles to the prevailing wind direction. Additional fly collections were made by replacing the sticky tubes with a strip of sheet metal (3¼ by 82 inches) clamped around the circumference of the wheel and coated with Tanglefoot on the outer surface. At the end of each collection the number of flies stuck on each of 24 equal sections of the metal strip was determined.

To compare the number of flies present further downwind from the CO_2 source, a sticky strip of sheet metal (3¼ by 350 inches), fashioned in the form of an arc, was placed 3 feet above ground and alternately for each collection at distances of 10 and 15 feet downwind from the center of the wheel. Flies were collected simultaneously from both the arc and the wheel while 300 cc/min CO_2 was being released from the center of the wheel.

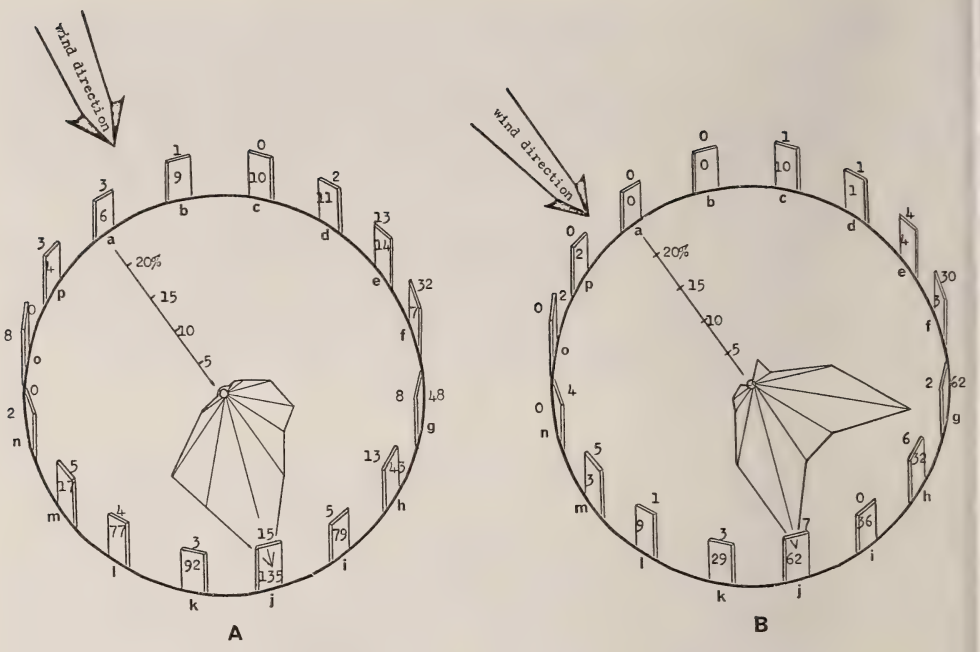
Results and Discussion

Approximately 85% of the flies caught in these tests were female *Simulium venustum* Say, the remainder included females of *Prosimulium fuscum* Syme and Davies and *Simulium (Eusimulium)* species, mainly *aureum* Fries (s.l.) and *latipes* (Meigen) (s.l.).

In five tests with the first apparatus (Figure 1), most flies were caught on the downwind pegs (Figures 3a and b). In fact, 84.5% of the 2,273 flies was collected on the downwind half of the wheel. A clearer comparison of the flies landing around the wheel is shown by a rosette representing the relative percentage of flies caught on each peg (Figures 3a and b). In spite of the striking preponderance of flies on the downwind pegs, in some tests there was a scattering of flies on either side of the prevailing wind direction (Figure 3a), although less marked in tests with more flies. The scattering may result from slight shifts in wind direction or from some flies not landing on the downwind pegs but penetrating between the pegs and landing on the side or upwind pegs. However, even when the wheel was modified to orient freely in response to shifting wind direction and with winds averaging 204 ft/min, some flies still were landing on the upwind side of the wheel (Figure 4a). In fact, in three tests only 77% of 464 flies landed on the downwind half of the wheel with winds ranging from 204 to 500 ft/min. When the dowels were replaced with the metal strip for two tests, almost all the flies landed on the downwind half of the wheel (92.5% of 389 flies) in winds of 650 and 320 ft/min (Figures 5a and b).

Three tests were made comparing simultaneously a wheel without CO_2 with one from which CO_2 was emitted centrally at a rate of 300 ft/min (e.g. Figures 4a and b). The ratio of flies landing on the wheel with CO_2 and on the one without CO_2 were 155:1, 120:1 and 189:5. The importance of CO_2 in the orientation of this species was pointed out previously by Fallis *et al* (1967) and for other simuliid species by Fallis and Smith (1964). Other control collections with CO_2 emission but in the absence of wind would have helped to show the importance of wind in the orientation of flying simuliids. Unfortunately, in only one test, early in 1967, was there a completely windless condition coupled with a high number of active black flies. At this time an almost similar number of flies was found on each of the 16 pegs around the wheel.

The distance from the source of CO_2 at which black flies can detect this gas was examined only as far as 15 feet from the center of the wheel (Figure 6). Four tests indicated that considerably fewer flies were present at 10 and 15 feet than at one foot from the CO_2 source (Table 1). However, it can be seen that the ratio of flies for any pair of distances from the CO_2 source was not always constant. Under field conditions variables, such as quantity of CO_2 released (Smith 1966; Fallis *et al* 1967), weather factors, and size of the fly population, may influence for any one collection the number of flies drawn to the CO_2 source. Nonetheless, these tests point out that under field conditions female simuliids, primarily *Simulium venustum,* fly upwind toward a source of carbon dioxide and will do so only when such gas is present.



Figures 3a and b. Diagrams showing number of female simuliids caught on the inner and outer surfaces of each peg and the relative percentage in each sector in relation to wind direction. Carbon dioxide emitted from center at 150 cc/min.

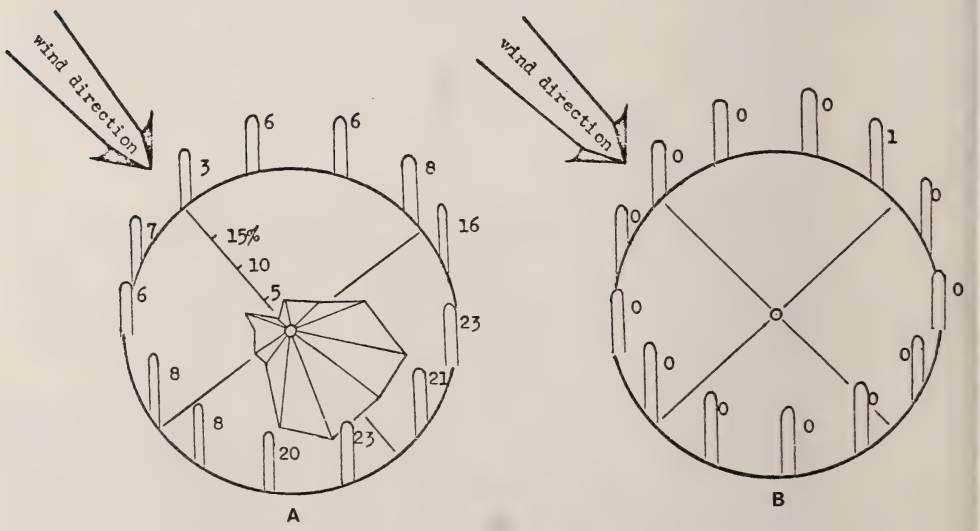
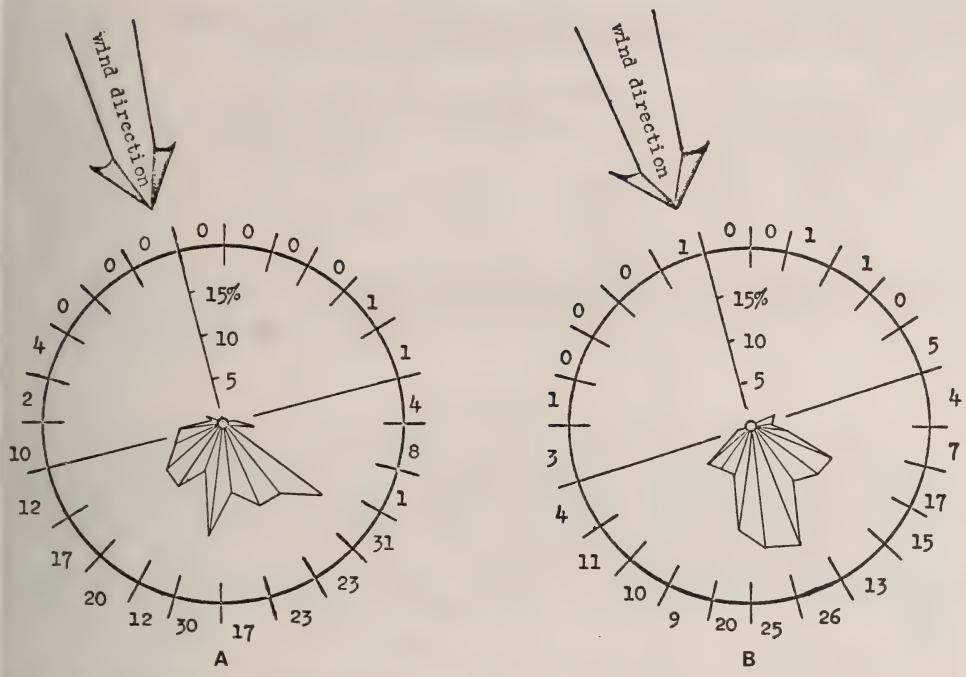


Figure 4. Diagram showing the effect of wind direction and carbon dioxide on the collection of female simuliids from sticky test tubes, a. Carbon dioxide emitted at 300 cc/min. b. No carbon dioxide emitted.



Figures 5a and b. Diagram showing the number and percentage of female simuliids collected from each section of the peripheral sticky metal strip in relation to wind direction. Carbon dioxide emitted from the center at 300 cc/min. Collection time 3 and 2 hours respectively.

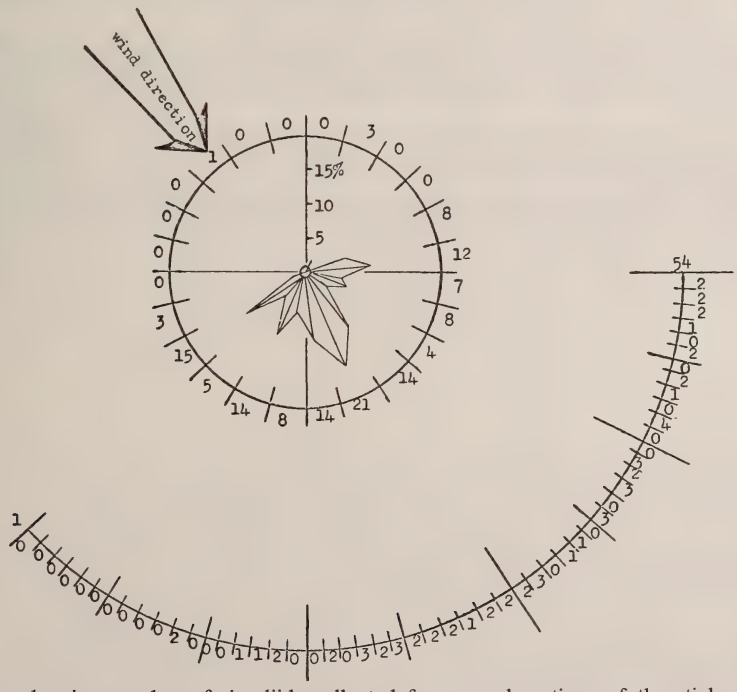


Figure 6. Diagram showing number of simuliids collected from equal sections of the sticky metal strips at 1 and 15 feet from the source of CO_2 which was released centrally at 300 cc/min. A rosette shows the percentage distribution of flies on the inner strip. Collection time, 90 min.

Table 1. Relative density of female simuliids on the downwind quadrants at various distances from the central source of CO_2 emission

No. of flies per square inch		Ratio of flies at paired distances from the source	Average wind speed (ft/min)
wheel	arc		
1.2[a]	0.054[b]	22:1[d]	610
2.0	0.034[b]	59:1	700
3.4	0.15[c]	23:1	350
10.3	0.78[c]	13:1	444

Distance from central source: [a]1 ft, [b]15 ft, [c]10ft, [d]from test shown in Figure 6

Acknowledgments

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THE LARVAL INSTARS OF *APHIDIUS PULCHER* BAKER (HYMENOPTERA : APHIDIIDAE)

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Abstract

Larvae of *Aphidius pulcher* were examined at 24-hour intervals during their development for changes in cuticular structure. Although there was no histological evidence of exuviae, the changes observed were interpreted as an indication of five larval instars. The external appearance of each instar is described.

Introduction

Aphidius pulcher is a common parasite of the pea aphid in southwestern Ontario. Its biology has recently been investigated by Schmidt (1970), who made no mention of the larval instars. Various authors have reported the number of instars for related parasite species, but there is little consistency among the numbers reported. Spencer (1926) states that *Diaeretus rapae* has four larval instars. Stary (1962) ascribes five larval instars to *Aphidius ervi* and Stary (1966) gives the figure three for all Aphidiidae. Johnson (1959), quoting Vevai, ascribes five to *Aphidius platensis,* while Griffiths (1961) states that *Monoctonus paludum* has four larval instars.

Very few authors give specific criteria or reasons for the stated number. Therefore, the larvae of *Aphidius pulcher* were described and, on the basis of mouthparts and other cuticular structures, the number of larval instars was determined.

Materials and Methods

The parasites were reared on the pea aphid *(Acyrthosiphon pisum),* clones of which were maintained on young broad bean plants. The cultures were kept in a greenhouse compartment that received both natural and artificial light (16L : 8D). The temperature ranged from 20° to 23°C.

Aphids 94 to 96 hours old (third instar) were allowed to be individually parasitized, with one egg being oviposited into each aphid. At 72 hours after oviposition, and at subsequent 24-hour intervals, parasites were dissected from the aphids, preserved in 70% alcohol, and drawn. Whole larvae were also mounted in Hoyer's medium and drawn from a slide. Heads, dissected from older larvae, were mounted separately to present an anterior view of the head. Approximately ten larvae were measured at each time interval, and the scales on the figures indicate the average measurements.

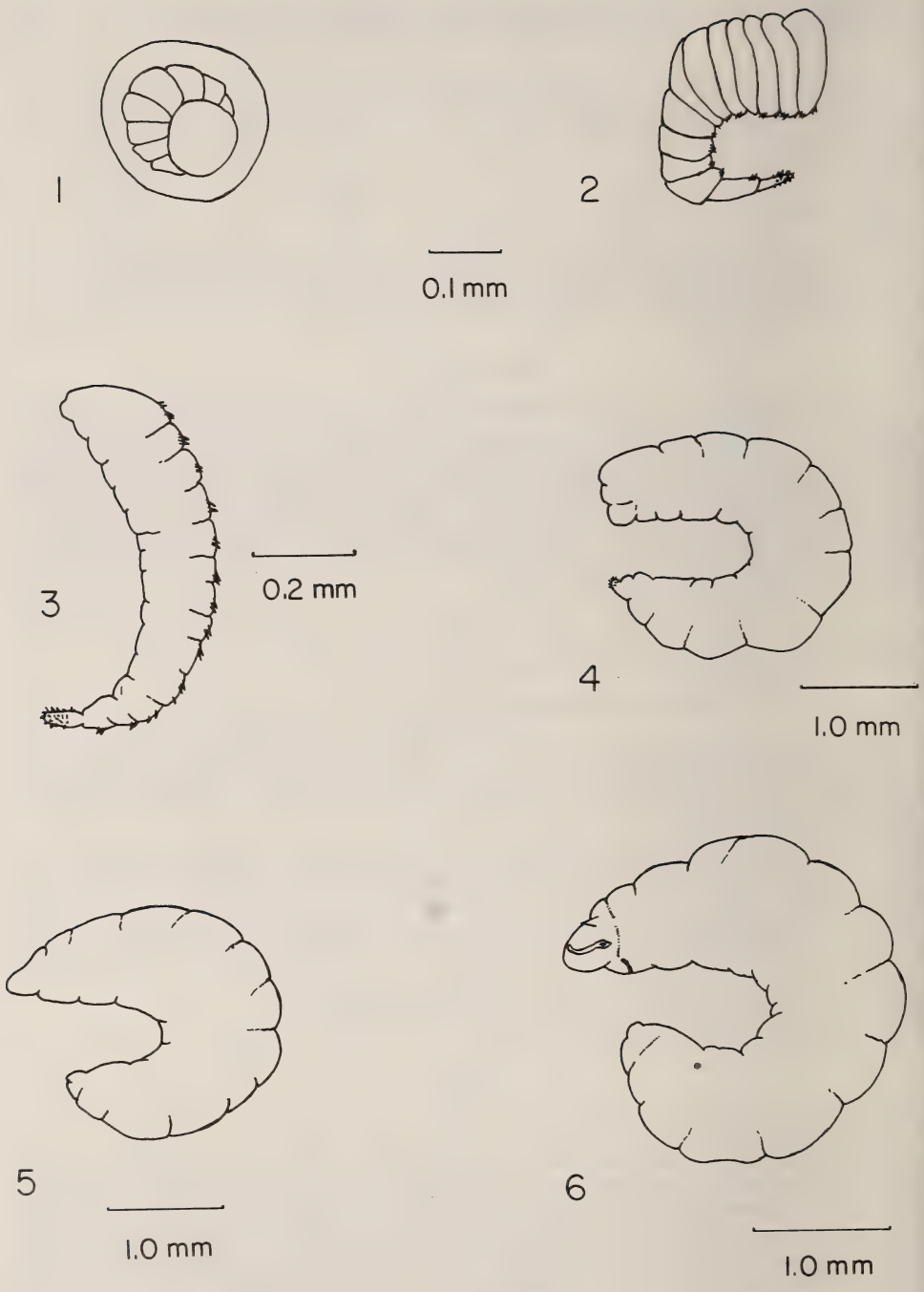
The labeling for the mouthparts is that used by Capek (1970).

Results

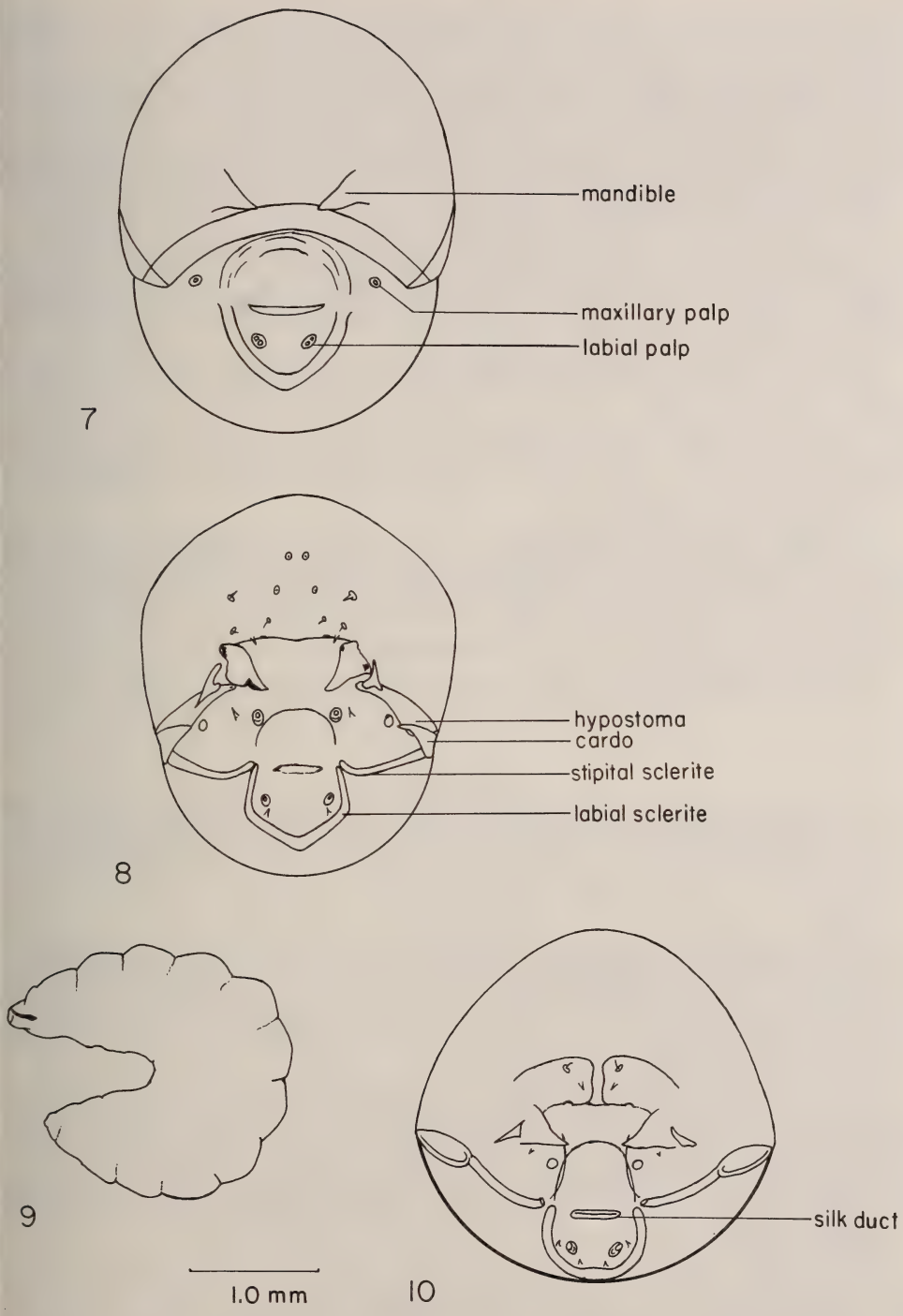
Description of the Larvae at 24-hour Intervals

Three days Either embryos or free larvae (Figures 1 and 2) were found on the third day after oviposition. Thus hatching occurred at this time. The first instar larva measured 0.2 mm in diameter anteriorly, tapering posteriorly to a cauda of 0.02 mm in diameter. Two pairs of small cuticular spines were found on each segment along one side of the body. The posterior third of the pointed cauda was also spiny. The body cuticle was very smooth, thin, transparent, and dissolved almost immediately when mounted in Hoyer's mounting medium. No mouthparts were visible.

Four days The larva (Figure 3) was slightly curved, in the opposite direction from that of the three-day-old larva. Similar spines were found along the dorsal side of the larva, and a similar area of the cauda was spiny. The diameter, anteriorly, was the same as that of the three-day-old, although the posterior region was considerably greater in diameter.



Figures 1-6. *Aphidius pulcher* immature stages, lateral views: 1, embryo; 2, three-day-old newly emerged larva, first instar; 3, four-day-old larva, first instar; 4, five-day-old larva, second instar; 5, six-day-old larva, third instar; 6, seven-day-old larva, fourth instar.



Figures 7-10. *Aphidius pulcher* immature stages: 7, head of third instar, anterior view; 8, head of fourth instar, anterior view; 9, eight-day-old larva, fifth instar, lateral view; 10, head of fifth instar, anterior view.

Internal growth had taken place, especially in the posterior region, but considering similarities in overall size and cuticular structures, this was considered to be the first larval instar.

Five days At five days the larva (Figure 4) had increased considerably in size, and was approximately 2 mm in length along the ventral surface. The body was U-shaped. Oral lobes were present, and the stipital sclerome was slightly sclerotized. There were no spines along the body, although the cauda, which was reduced to a hump, was covered by small spines. Because of the differences between this larva and the four-day-old larva, this was considered to be the second instar larva.

Six days The larva (Figure 5) had again increased in size, and the body was thicker than at five days. The cauda was more reduced and was not spiny. The head region was elongated, and various mouth parts were visible (Figure 7), although only lightly sclerotized. Most prominent were the mandibles, and palps of the maxillae and labium. This was considered to be the third instar larva.

Seven days At seven days from egg deposition, the head region was better defined (Figure 6). No increase in size had taken place during the six to seven days of development. The number of structures on the head had increased. Sensory pits, hairs, and spines were visible and the mandibles were well sclerotized (Figure 8). The cardo, hypostoma, stipital and labial sclerites were visible as definite structures. The mouthparts of this larval instar were quite different from those of the six-day-old larva, therefore this was considered as the fourth instar.

Eight days (Figure 9) The mouthparts of the larva had changed considerably. The labial sclerite was different in shape, and the stipital sclerite and cardo were heavier and darker than in the seven-day-old (Figure 10). The silk duct opening was well sclerotized, but the mandibles were reduced. These differences from the seven-day-old indicate that the larva had molted within the last 24 hours, making this the fifth instar. The pupa could be seen inside the cuticle of this larva.

Pupa and Adult At 10 days, the pupa formed and the adults emerged at 12 to 13 days.

Discussion

This paper agrees with Stary's (1962) and Johnson's (1959) papers in reporting five larval instars for this genus of Aphidiidae. It disagrees with the view of Stary (1966), that all Aphidiidae have three larval instars. It is possible, but in the author's opinion unlikely, that different species have different numbers of larval instars as the literature would indicate.

The criteria used in this paper, obtained by observing the changing cuticular structures, seems to be the only practical way of determining the number of instars in this insect. The very thin exocuticle of the earlier instars (the endocuticle is digested by molting fluid), after being shed, seems to be absorbed into the aphid hemolymph, and it could not be found. Histological sectioning of the parasites for other purposes, at no time revealed a double cuticle as would be expected before a molt.

As can be seen, the greatest increases in size occurred between four and five days, and between five and six days. The first time the mouthparts were prominent was at six days. Eight-day-old larvae, taken from mummified aphids, had already spun cocoons inside the aphid cuticle. This corresponds with the well-sclerotized silk duct opening at this stage. Observation of histological sections revealed the oral opening to be located in between, and just below the mandibles. However, the oral opening was not visible as a definite cuticular structure.

Acknowledgments

This research was conducted as part of the requirements for an M.Sc. degree under the supervision of Dr. J. A. George, Department of Zoology, University of Western Ontario. It was supported by NRC grant No. A4658.

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STUDIES OF THE BYRON BOG IN SOUTHWESTERN ONTARIO XLV. INSECTS ASSOCIATED WITH FLOWERING DANDELION, *TARAXACUM OFFICINALE* WEBER

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Abstract

On May 7, 1969, 152 insects in Collembola, Thysanoptera, Hemiptera, Homoptera, Coleoptera, Diptera, and Hymenoptera were collected from flowering heads of dandelion, *Taraxacum officinale.*

Introduction

The Byron Bog has been described by Judd (1957). There are three zones in it. The central part, Zone A, is a floating mat of *Sphagnum,* including a pond, Redmond's Pond. Surrounding Zone A is Zone B, which is damp or flooded throughout the year and which supports a considerable growth of trees and shrubs. The outer region is Zone C, consisting of relatively dry, wooded slopes.

In 1967 and 1968, a parking lot and field house were constructed in the northeast corner of Zone C. In August 1968 loads of topsoil were deposited around the field house and on August 13, 1968, this soil was levelled and seeded with grass. A square, grassy lawn 25 by 25 yards was produced adjacent to the south side of the field house. This considerably altered the terrain which had until then been part of a sloping, weedy hillside, and allowed the establishment of lawn-dwelling weeds which were not normally found in Zone C. Among these weeds was the dandelion, *Taraxacum officinale* Weber.

On May 7, 1969, dandelions were in bloom on the lawn and collections of insects were made from them between 1:00 and 3:00 p.m. The sky was clear, there was no wind and the temperature was 75° F. Other plants on the grassy lawn were low weeds, the only one in bloom besides dandelion being shepherd's purse, *Capsella Bursa-pastoris* (L.) Medic.

Insects were collected from the flowering heads of dandelion with an aspirator and were then put in poison jars and later pinned or preserved in fluid. The insects were identified by the following taxonomists (ERI refers to the Entomology Research

Institute, Department of Agriculture, Ottawa): G. L. Ayre, Entomology Research Institute, Belleville, Ontario (Formicidae), D. Brown, ERI (Hemiptera, Homoptera), K. Christiansen, Grinnell College, Grinnell, Iowa (Collembola), R. deRuette, ERI (Coleoptera), H. E. Milliron, ERI (Halictidae, Apidae), K. O'Neill, U.S. Department of Agriculture, Beltsville, Maryland (Thysanoptera), B. V. Peterson, ERI (Chloropidae), J. R. Vockeroth, ERI (Syrphidae), C. M. Yoshimoto, ERI (Eurytomidae). All specimens are deposited in the collection of the Department of Zoology, University of Western Ontario, except some noted as "kept", which are in the collections of the institutions in which they were identified.

Account of Insects Collected

Altogether 152 insects were collected representing Collembola, Thysanoptera, Hemiptera, Homoptera, Coleoptera, Diptera and Hymenoptera. Most of these were bees which were well dusted with dandelion pollen. Others were insects which feed on pollen and nectar. Two groups of predatory insects were represented, Anthocoridae and Nabidae.

Collembola

Sminthuridae

Bourletiella arvalis Fitch—10 springtails (kept). Maynard (1951) records that this species is common in late spring and occurs in large numbers on grass and all low vegetation.

Bourletiella hortensis Fitch—12 springtails (kept). Maynard (1951) records that this is a widely recognized economic species and is very abundant on ground that has been in cultivation the previous year.

Thysanoptera

Thripidae

Frankliniella tritici (Fitch)—3 thrips (1 kept). Leonard (1928) records this species from various plants and Judd (1964) collected it at London at the end of April from marsh marigold.

Hemiptera

Miridae

Lygus lineolaris (Beauv.)—4 bugs. This species was previously recorded from London on wild carrot by Judd (1970).

Anthocoridae

Orius tristicolor (White)—1 bug. This species was previously recorded from London on wild carrot by Judd (1970).

Nabidae

Nabis ferus (L.)—2 bugs. This species was previously recorded from London on wild carrot by Judd (1970).

Homoptera

Membracidae

Cyrtolobus sp.—1 tree-hopper.

Coleoptera

Carabidae

Lebia moesta Lec.—1 ground beetle. The presence of this beetle is in accord with the report of Ball (1960) that beetles of the genus *Lebia* may be found climbing about on plants in broad daylight.

Coccinellidae

Coleomegilla maculata lengi Timb.—29 beetles. This species has been reported previously from London on marsh marigold by Judd (1964) and on wild carrot by Judd (1970).

Coccinella trifasciata perplexa Muls.—1 beetle. The presence of this beetle accords with the report by Dillon and Dillon (1961) that it may be taken by sweeping herbs.

Curculionidae

Barini–1 beetle. Dillon and Dillon (1961) record that beetles of several species in the Tribe Barini are found on various flowers.

Diptera

Syrphidae

Helophilus lunulatus Mg.–1 female hover-fly. This species was previously found in London in May on marsh marigold (Judd, 1964).

Chloropidae

Oscinella carbonaria (Loew)–2 flies. Flies of this family are commonly collected by sweeping grass and other low herbage and some frequent flowers, as reported by Stone *et al* (1965) who also report *O. carbonaria* as occurring in Ontario.

Hymenoptera

Eurytomidae

Tetramesa sp.–1 wasp. Muesebeck *et al* (1951) include *Tetramesa* as synonymous with *Eurytoma,* a genus that includes wasps parasitic on many species of insects.

Formicidae

Tapinoma sessile (Say)–6 ants

Lasius (? neoniger Emery)–4 ants

Formica fusca L.–1 ant

Formica lasioides Emery–1 ant

These ants are widely distributed in North America and occur in a variety of habitats (Muesebeck *et al,* 1951).

Halictidae

Halictus sp.–1 bee

Lasioglossum sp.–1 bee

Dialictus spp.–33 bees (8 kept)

Sphecodes sp.–1 bee

Augochlorella spp.–13 bees (7 kept)

Bees of these genera are widely distributed in North America (Muesebeck *et al,* 1951) and several species have been reported previously from the Byron Bog on boneset by Judd (1969).

Apidae

Ceratina spp.–19 bees (7 kept)

Apis mellifica L.–3 bees

Various species of *Ceratina* occur on flowers (Muesebeck *et al,* 1951) and *A. mellifica* was previously collected in the Byron Bog on boneset (Judd, 1969).

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SPIDERS OF HEASMAN'S FIELD, A MOWN MEADOW NEAR BELLEVILLE, ONTARIO

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Abstract

Intensive sampling of the arthropod population in a small meadow by "quick trap" and vacuum sampler for five years yielded about 8% entomophagous individuals, of which 43% were spiders. Spiders averaged about 53/m^2 in population density. The resident, most abundant species were *Argenna obesa, Ceraticelus emertoni, Ceraticelus similis, Dictyna terrestris, Eperigone trilobata, Eridantes erigonoides, Erigone autumnalis, Pardosa saxatilis,* and *Pirata minutus,* which together averaged 39/m^2, or 73.6% of total spiders. Thirty-three other species were also residents of the meadow but were at lower population densities, while an additional 108 species were taken sporadically.

In a small seeded meadow, known locally as Heasman's field, near Belleville, Ontario, a study was begun in 1962 to elucidate the population dynamics of grassland mesofauna (Turnbull, 1966). A sampling method utilizing the "quick-trap" and vacuum sampler developed by Turnbull and Nicholls (1966) proved satisfactory and was used consistently during the period 1966-70 in an iterative study of the arthropods in the meadow.

As Turnbull (1966) noted, the field was sown to forage grasses and legumes in 1960, but was subjected to overgrazing by cattle in 1961, so that the field became invaded by field horsetail (*Equisetum*) and plantain (*Plantago*). In more recent years the horsetail has declined, but plantain, quack grass (*Agropyron*), crabgrass (*Digitaria*), foxtail grass (*Setaria*), sheep sorrel (*Rumex*), black medick (*Medicago*), ragweed (*Ambrosia*), and oxeye daisy (*Chrysanthemum*) all formed large percentages of the plants in the meadow. A systematic sampling in 1970 showed that fodder grasses and legumes constituted less than 50% of the plants.

Two plots of 2000 m^2 each were defined on an east-facing slope of the meadow. Plot 1 was on the upper, eroded part of the slope, and Plot 2 on the lower, moister part. Nine samplings, each consisting of 20 random, ½m^2 vacuum samples, were collected on each plot over a period of four consecutive days (weather permitting) each year (eight samplings in 1966). Thus each sampling extracted the surface and herb-dwelling mesofauna from 1/100th of the total plot area. As the samplings were distributed at two- or three-week intervals from April to October, the sampling is not thought to have removed a damaging proportion of the arthropods. The collected arthropods were separated from litter by Tullgren funnel, further separated from sand by saltwater flotation, and sorted under the microscope to specified categories. Drying and weighing for biomass determination, results of which will be reported later, completed the measurements.

The Spider Population

This paper gives preliminary data on the kinds and numbers of spiders. These predators comprised 43% of the predator population, the remainder being myrmecine ants or certain Coleoptera or Hemiptera. The predator:parasitoid ratio was approximately 3:1, and the combined entomophagous groups formed about 8% of the arthropods in the samples. Total spiders on the meadow were estimated at about $53/m^2$. Selected samplings in 1967 gave standard errors that ranged from 2 to 18% of the mean for both plots combined, i.e., in 40 samples. This error became less than 10% with logarithmic transformation of the original data. The error at species level is expected to be much higher, as the majority of species are extremely rare and as their distributions, on preliminary examination, appear to be clumped.

The species of spiders found in Heasman's field during the five-year sampling period are listed here in three functional groups. That the sampling program failed to take all of the species inhabiting the meadow is evident from the appearance of some 20 additional species in pitfall traps placed about the meadow. This kind of trap is generally believed to measure primarily the activity of arthropods and only to a minor (though unknown) extent the population density.

Our solution to the problem of identifying the masses of immature spiders to species was as follows: when a single species of a genus was found to be represented among adults, all immature stages of the genus were identified as that species. When two or more species of a genus were found, the immature stages were reared and examined for color or size, differences that would indicate different times of maturity in the season. In this way, for example, two closely-similar species of *Schizocosa* were detected (Dondale, 1969). More difficult were the immature stages of two or more congeneric species that offered no distinguishing features of these kinds; for example, *Ceraticelus* spp., *Clubiona* spp., and *Xysticus gulosus* and *X. pellax* are readily identifiable to genus, but not to species. In such cases we resorted to assignment of the immature stages to species in the proportion found among the adults. This practice, which was based on untested assumptions, probably introduced bias into the population data. Finally, the immature stages of Erigonidae, about 6% of total spiders, were apportioned among the six principal species of this family in the same way. The immature stages of certain families or genera that contained only rare species, *e.g.,* Gnaphosidae, Clubionidae (other than *Clubiona* spp.), and *Dictyna* (other than *D. terrestris*), were identified only to family or generic levels.

Resident Abundant Species

Nine species of spiders occupied the meadow at all seasons of the year. They reproduced there, and their numbers reached an annual mean of at least $2/m^2$ of meadow surface in random, $½m^2$ samples, on either of the two plots in two or more years. Population levels for these species are given in Table I. Collectively they account for 73.6% of total spiders. This category does not, of course, include species that exceeded $2/m^2$ at certain times of the year (such as the hatching period) but which could maintain only very light populations in other stages of development. Of the following, all except *Pirata minutus* and *Pardosa saxatilis* are small web-builders.

Argenna obesa Emerton
Ceraticelus emertoni (O. Picard-Cambridge)
Ceraticelus similis (Banks)
Dictyna terrestris (Emerton)
Eperigone trilobata (Emerton)
Eridantes erigonoides (Emerton)
Erigone autumnalis (Emerton)
Pardosa saxatilis (Hentz)
Pirata minutus (Emerton)

Table 1. Population densities of some resident spiders in Heasman's field (no./m^2)

Species	1966		1967		1968		1969		1970		Mean	
	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
Erigone autumnalis	1.86	19.51	4.11	28.23	4.80	28.38	4.79	17.22	4.16	15.54	3.94	21.78
Ceraticelus emertoni	4.18	5.90	9.07	9.12	16.08	16.06	8.29	15.80	7.49	17.18	9.02	12.81
Pirata minutus	.99	11.59	.71	7.84	.84	4.82	.83	3.21	1.32	4.06	.94	6.30
Eperigone trilobata	.73	3.99	.40	5.31	1.17	9.06	.62	6.09	.59	2.68	.70	5.43
Argenna obesa	.33	8.73	.31	5.64	.06	1.37	.12	.37	0	.13	.16	3.25
Dictyna terrestris	2.65	.76	2.12	.19	3.52	.32	3.71	.13	4.24	.14	3.25	.31
Eridantes erigonoides	.64	2.74	.90	3.28	1.28	3.21	1.54	3.01	2.13	3.17	1.30	3.08
Ceraticelus similis	.30	4.08	.43	3.22	.69	3.60	.07	2.57	.16	3.73	.33	3.44
Pardosa saxatilis	.63	4.43	.30	1.61	.22	2.03	.31	1.59	.13	.82	.32	2.10
Talavera minuta	1.20	1.69	1.02	1.72	1.39	1.97	.89	1.23	.86	1.39	1.07	1.60
Clubiona johnsoni	.66	.80	.53	1.49	.70	1.73	.56	1.41	.63	1.41	.62	1.37
Enoplognatha marmorata	.23	3.65	.16	1.18	.46	.76	.30	.32	.36	.26	.30	1.23
Clubiona abboti	.05	2.13	.16	1.27	0	.92	.03	1.41	0	.52	.05	1.25
Schizocosa avida	.45	1.48	.24	1.31	.34	1.02	.07	.66	.04	.50	.23	.99
Xysticus discursans	.41	1.14	.18	.77	.41	.54	.34	.66	.50	1.12	.37	.85
Ceraticelus micropalpis	.08	0	.77	.04	1.37	0	1.13	.07	1.14	.83	.90	.19
Schizocosa crassipalpis	.40	.78	.26	.91	.30	.92	.26	.52	.23	.50	.29	.73
Habronattus decorus	.90	1.00	.27	.53	.19	.48	.04	.51	.08	.78	.30	.66
Neoantistea agilis	.48	1.94	.13	.91	.12	.37	.14	.24	.11	.13	.20	.72
Steatoda americana	.53	1.06	.24	.88	.09	.61	0	.47	.04	.38	.18	.68
Walckenaera vigilax	.18	.91	.17	.46	.22	.41	.23	.80	.29	.78	.22	.67
Sub Total	17.88	78.31	22.48	75.91	34.25	78.58	24.27	58.29	24.50	56.05	24.68	69.43
Other spiders	6.35	10.00	4.58	8.17	5.67	6.31	5.84	5.95	4.74	5.33	5.43	7.15
Total spiders	24.23	88.31	27.06	84.08	39.92	84.89	30.11	64.24	29.24	61.38	30.11	76.58

Resident Rare Species

These species were also observed to occupy the meadow at all seasons, and reproduce there, but their annual mean population densities did not exceed $2/m^2$ in any year. Collectively they averaged $11.5/m^2$. Population levels for the most abundant of the 33 species are given in Table I.

Arctosa emertoni Gertsch
Argiope trifasciata (Forskal)
Ceraticelus micropalpis (Emerton)
Ceratinops crenatus (Emerton)
Clubiona abboti L. Koch
Clubiona johnsoni Gertsch
Collinsia plumosus (Emerton)
Dictyna hentzi Kaston
Enoplognatha marmorata (Hentz)
Habronattus decorus (Blackwall)
Habronattus viridipes (Hentz)
Lycosa frondicola Emerton
Neoantistea agilis (Keyserling)
Oxyptila americana Banks
Oxyptila conspurcata Thorell
Pachygnatha tristriata C. L. Koch
Pardosa distincta (Blackwall)
Pardosa moesta Banks
Phidippus clarus Keyserling
Phidippus princeps (Peckham)
Schizocosa avida (Walckenaer)
Schizocosa crassipalpis (Emerton)
Schizocosa heasmani Dondale
Steatoda americana (Emerton)
Talavera minuta (Banks)
Thanatus formicinus (Clerck)
Walckenaera vigilax (Blackwall)
Xysticus alboniger Turnbull *et al*
Xysticus ampullatus Turnbull *et al*
Xysticus discursans Keyserling
Xysticus gulosus Keyserling
Xysticus luctans (C. L. Koch)
Xysticus pellax O. Picard-Cambridge

Other Rare Species

These 108 species were taken sporadically in the meadow. None became abundant in any year, and for many the habitat relationships were not determined. Ecologically they probably exert little effect in the meadow ecosystem, as collectively they averaged only $2.5/m^2$ during the five years. Several, *e.g., Schizocosa saltatrix, Mangora* spp., *Tetragnatha* sp., *Theridion* spp., *Coriarachne versicolor, Philodromus* spp., *Tmarus angulatus,* and *Xysticus punctatus,* are in fact believed to be forest spiders, and the individuals found in the meadow were immature stages that had presumably "ballooned", "bridged", or wandered from nearby woods and hedgerows. They would probably find the treeless meadow a hostile environment.

Acanthepeira stellata (Walckenaer)
Agelenopsis potteri (Blackwall)
Amaurobius bennetti (Blackwall)
Anyphaenella saltabunda (Hentz)
Araneus sp.
Araniella displicata (Hentz)

Argyrodes trigonum Emerton
Bathyphantes concolor (Wider)
Callilepis imbecilla (Keyserling)
Callioplus sp.
Castianeira descripta (Hentz)
Castianeira gertschi Kaston
Castianeira longipalpis (Hentz)
Centromerus sylvaticus (Blackwall)
Ceraticelus atriceps (O. Picard-Cambridge)
Ceraticelus bulbosus (Emerton)
Ceraticelus laetus (O. Picard-Cambridge)
Ceraticelus ornatulus Crosby and Bishop
Ceraticelus paschalis Crosby and Bishop
Ceraticelus rugosus Crosby
Ceratinella brunnea Emerton
Ceratinops latus (Emerton)
Ceratinopsis auriculata Emerton
Coriarachne versicolor Keyserling
Cornicularia directa (O. Picard-Cambridge)
Cornicularia indirecta (O. Picard-Cambridge)
Crustulina sticta (O. Picard-Cambridge)
Dapanus mirus (Walckenaer)
Dictyna annulipes (Blackwall)
Dictyna coloradensis Chamberlin
Dictyna foliacea (Hentz)
Dictyna volucripes Keyserling
Drassyllus depressus (Emerton)
Drassyllus niger (Banks)
Enoplognatha ovata (Clerck)
Enoplognatha tecta (Keyserling)
Erigone atra Blackwall
Evophrys monadnock Emerton
Floricomus emertoni Bryant
Frontinella pyramitela (Walckenaer)
Gnaphosa parvula Banks
Grammonota ornata (O. Picard-Cambridge)
Grammonota sp. near *inornata* Emerton
Haplodrassus hiemalis (Emerton)
Haplodrassus signifer (C. L. Koch)
Hentzia sp.
Icius sp.
Islandiana flaveola (Banks)
Lycosa helluo Walckenaer
Mangora gibberosa (Hentz)
Mangora placida (Hentz)
Maso sp.
Meioneta simplex (Emerton)
Meioneta unimaculata (Banks)
Meioneta zygia (Keyserling)
Metaphidippus galathea (Walckenaer)
Metaphidippus protervus (Walckenaer)
Micaria gertschi Barrows and Ivie
Micaria montana Emerton
Microlinyphia mandibulata (Emerton)
Misumena vatia (Clerck)
Misumenops asperatus (Hentz)

Neoantistea radula (Emerton)
Neoscona arabesca (Walckenaer)
Neriene clathrata (Sundevall)
Pachygnatha dorothea MacCook
Paraphidippus marginatus (Walckenaer)
Pardosa milvina (Hentz)
Pardosa modica (Blackwall)
Peckhamia picata (Hentz)
Pellenes hoyi (Peckham)
Philodromus cespitum (Walckenaer)
Philodromus exilis Banks
Philodromus rufus vibrans Dondale
Phrurolithus pugnatus Emerton
Phrurotimpus alarius (Hentz)
Phrurotimpus borealis (Emerton)
Pirata arenicola Emerton
Pirata insularis Emerton
Pirata marxi Stone
Pirata piraticus (Clerck)
Pocadicnemis pumila (Blackwall)
Porrhomma terrestris (Emerton)
Salticus scenicus (Clerck)
Schizocosa saltatrix (Hentz)
Scylaceus pallidus (Emerton)
Sergiolus decoratus Kaston
Sergiolus variegatus (Hentz)
Sitticus pallustris (Peckham)
Souessa spinifera (O. Picard-Cambridge)
Steatoda borealis (Hentz)
Tapinocyba simplex (Emerton)
Tapinopa bilineata Banks
Tetragnatha versicolor Walckenaer
Thanatus striatus C. L. Koch
Theridion differens Emerton
Theridion frondeum Hentz
Theridion murarium Emerton
Theridion petraeum L. Koch
Tibellus oblongus (Walckenaer)
Tmarus angulatus (Walckenaer)
Trochosa terricola Thorell
Uloborus sp.
Xysticus elegans Keyserling
Xysticus emertoni Keyserling
Xysticus punctatus Keyserling
Xysticus triguttatus Keyserling
Zelotes subterraneus (C. L. Koch)

Discussion

The number of species of spiders found in five years was 150, though in any single year the number ranged from 80 to 99. Many were found only once or twice during the study. The yearly total is, however, approximately double the number found in the same meadow in 1962 in Turnbull's (1966) collections. Turnbull's prediction of about 10 additional species from a hypothetical tenfold increase of sampling intensity (based on the relationships between number of individuals, number of species observed, and the

calculated index of species diversity) has therefore been far exceeded in the present study, in which that increase in sampling intensity was accomplished. The explanation for this is believed to be the vegetative changes in the meadow between the two studies. The surface sampled by Turnbull was severely overgrazed, and characterized by "tall clumps of mixed weeds, separated, especially on the high end of the field, by wide spaces of sparsely covered soil." From 1965 onward there was no grazing by cattle, the hay being cut and removed twice annually instead. Plant diversity was greater, and the ground cover was 100%. Cherrett (1964) showed a tentative correlation between the amount of shade, which may act as a token stimulus for moisture or other factors, and the presence of several species of grassland spiders in the British uplands. A study of distributions on Heasman's field is in preparation.

The species hierarchy in the meadow also changed with time. *Pardosa saxatilis* constituted about 22% of total spiders in 1962, while a second wolf spider, *Pardosa milvina,* constituted 20%. Third in abundance was *Ceraticelus emertoni* at 17%. In the more verdant condition of the meadow in the present study, *P. saxatilis* has not exceeded 5% of total spiders in any year and may be declining with time, *P. milvina* has virtually disappeared, and *C. emertoni* has assumed second place in abundance, after *Erigone autumnalis* (Table I). *Ceraticelus* spp., *E. autumnalis,* and *Pirata minutus* also dominated the spider populations in the meadow and pastures studied by Wolcott (1937) in upper New York State.

Population density of the spiders in Heasman's field is comparable with that found by other workers in various kinds of temperate grassland. The estimate of $53/m^2$ is higher than the $4.9/m^2$ found on nearly bare ground at Rothamsted by Morris (1922), but is similar to the 29 to $77/m^2$ taken on grazed limestone soil in the Pennine moors (Cherrett, 1964), to the $45.5/m^2$ on the Strzeleckie Meadows, near Warsaw (Breymeyer, 1967), and to the $44.2/m^2$ on Heasman's field in 1962 (Turnbull, 1966). It is also like the $50.6/m^2$ found in pasture and meadow in New York (Wolcott, 1937), the $56/m^2$ found in Tennessee (Van Hook *et al,* 1970), and the $62.1/m^2$ in a "dry" hayfield at Lindfield in midsummer (Bristowe, 1939), and little different from the estimates of $68.8/m^2$ and $76.7/m^2$ taken on undisturbed and mown headlands, respectively, at Silwood Park (Southwood and van Emden, 1967). Estimates of 100 to $842/m^2$ have been made for various British pastures and meadows on good soil (summarized by Bristowe (1939) and Cherrett (1964)). Duffey (1956) estimated a mean population density of $597/m^2$ during a 12-month period in grassland in Wytham Wood, though this number included only the so-called aeronautic spiders and selected non-aeronauts. If the five genera of non-aeronauts for which he gives no quadrat data are added to this, the population level of spiders may reach $1000/m^2$, which would represent the highest spider population on record for grassland. These estimates, though derived from quantitative sampling methods comparable to the one used in Heasman's field, are based on relatively short periods of time (in some instances, on a single sampling).

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WHAT DOES AGRICULTURE EXPECT OF APPLIED ENTOMOLOGY?

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Abstract

A discussion of the role of applied entomology in control of pests of agricultural crops.

In dealing with this topic, I think it would be fair to give some definitions of terminology, which will give you a better idea of the kind of bias base from which I speak.

First, let me give my definition of "applied". In general, the word is used in discussion research, along with its co-word "basic". So here is my first bias—there are only two kinds of research, good and bad! In my terms of reference, research can be good but very basic; likewise, research can be good and very applied. Of course, both can be bad—hopefully not often. As far as I am concerned, the dollars spent in entomological research (agriculture) should be spent for mission-oriented work only. I'll discuss this more fully later in the talk.

Anyone working for agriculture either at the research or extension level must realize that agriculture is big business. This simply is my second bias. When we are working in programs for agriculture, we must be fully aware of the farmers' problems. We in extension programs feel we are the link between farmers and research people, and vice versa. We in extension programs are farmer-oriented. Whether we are talking about entomology problems or other production problems.

I suppose it's natural to think about pesticides when dealing with applied entomology. Thus, the third bias is that I believe farmers could not be producing crops or livestock on an economic basis if pesticides were not available to control the many pests attacking those segments of their business.

Finally, much has been said regarding pesticide usage in food production, painting the farmer as the villain in overuse and/or misuse of pesticides. Where there has been overuse and/or misuse, much of the blame must come back to those of us associated with the research programs. Farmers would be better off financially if they did not have to

apply chemicals for pest control. Let me state again that farming is big business and add that most farmers understand more about living systems than we give them credit for. Those who have suggested that we ban the use of all pesticides for a five-year period are obviously speaking from a fairly secure position in an ivory tower, or have been submerged so long that reality is no longer a concern.

Now that I have exposed my biases, I will move onto the task assigned.

Present Situation

A weakness of entomological research has been that too often the scientist studied a certain aspect of an insect, perhaps control materials. As a result of limited study, we have developed chemicals to control the particular pest and quite often high rates of chemical and repeated applications are required. Control was achieved and everyone was happy until someone questioned overkill, overdose, contamination of environment, etc.

To put the problem quite simply, in most cases, we do not have enough data on the total ecology of the particular pest. We do not, in most cases, know what level of infestation constitutes an economic threat to the crop. If our extension workers had critical threshold values for the many pests that we have to control, I am convinced that our pesticide load could be reduced considerably. It is my opinion that these critical *threshold values must be established for all major pests as soon as possible.*

It is not enough to know only the total ecology of the pest, as that particular pest fits into a much larger system. It is important to put together the big picture of the large system before making final judgments.

The Big Farm Picture

When one looks at a farming system, he should see that the farm is made up of at least three subsystems. First of all, there is the cropping system; on a livestock farm I call livestock the marketing system; and finally there is the equipment and storage system which ties the first two together. It is most important, when our crop specialists make recommendations on a crop, a variety, a system of management, pest control, a system of storage, that they realize that their recommendation has an impact across the total system. They must appreciate that their recommendations are measured in terms of dollars and cents, usually after milk or meat has been sold. This farm picture is typical of those where indirect foods are produced from the crops. Horticultural crops are direct food items in the main, but the three subsystems still apply.

If the big system applies to our crop specialists, then it surely must apply to research scientists. It is my view that far too few scientists have grasped the big picture in their research programs.

Present Problems In Crop Production

It might be useful to look at some specific insect problems that face our crop specialists today. In field corn, borer is a major problem. What level of infestation is economically serious? What techniques can be used to evaluate the damage? Will plant breeding to increase stalk strength be an answer? In monocultural systems, is plowing down of corn refuse a practical control practice? One of our specialists noted that in September and October a high percentage of borers were in the base of the plant where the forage harvester (ensilage corn) would miss them in cutting the plants. Is this a typical situation?

These questions on corn borer demonstrate the need for more information on threshold requirements.

In the tobacco area, one of our specialists indicated his concern about the cutworm problem. We are told that the dark-sided cutworm is the predominant species. Yet when light traps were set up, only a few moths of that species were picked up and larger numbers of other supposedly minor species were collected. The question was raised—are

light traps a satisfactory tool for monitoring cutworm infestations? *I am of the opinion that an important need is the establishment of reliable monitoring devices and services.*

Are we going in Circles?

Concern about the quality of the environment called for a dusting off of some of the cultural control methods that were used years ago. But agriculture has changed greatly in the past few years. Do these old methods still work under present conditions? We tend to go in circles in many things we do; perhaps we should find out the direction we are going on cultural control.

Mission-oriented Research

Mention was made of mission-oriented research at the start of this presentation. As indicated, research can be very mission oriented, but very basic as well. Personally, I feel that the dollars going into agriculture research should only be spent on mission-oriented research. This approach demands that desired goals are adequately outlined and puts the onus on research managers to make sure that goals are actual, attainable, and responsible.

In my opinion, there is room for long-range or futuristic research in mission-oriented programs. However, this long-range research must not give the scientist the divine right to hole up somewhere and use his type of research as a crutch to defend his lack of productivity when his director asks for a progress report. In far too many cases, long-range research has developed research scientists with tunnel vision.

Agriculture has a right to expect stronger mission-oriented research programs in the future than has been the case in the past.

Future Requirements

Modern agriculture is changing rapidly. Farmers are told that if they are doing things the same way they did five years ago, they are probably behind in technology. Whether this is entirely true, can be debated, but there can be no doubt that agriculture is in a state of rapid change.

This situation demands that research keep pace, particularly if research is giving leadership to the farmers. We know that in many areas of pest control, the best farmers are way ahead of the present research and extension knowledge. So the question is, who is giving leadership to whom?

In the future, we must have closer cooperation between all research agencies at the scientist level, so that problems are discussed as a team. This approach would make the crop production researcher more aware of present development by his colleagues in pest control and vice versa. For example, why should we not form a team composed of an entomologist, a pathologist, a plant breeder, and a crop specialist to do a complete study of problems related to field corn production? Too often in the past, we have stuck to our own specialities and not concerned ourselves with other research disciplines.

I spent four years here at the Vineland complex, and the lack of communication between researchers in the crop production unit and those in the entomology-pathology unit was most evident. If it had not been for our crop extension specialist, communication probably would not have taken place at all. In my opinion, the best solution for the Vineland research units would be to combine them under one Director.

Let me give you an actual example of a team working on a pest problem, and taking into account the total system. The pest problem was alfalfa weevil—a pest of increasing importance in Ontario. Our staff was told by entomologists that certain insecticides would control the pest. Our men wanted to know whether chemical control was an economic recommendation. The team approach was used and included the following:

– entomologist – crop specialist	Soils and Crops Branch
– entomologist (s) – crop research scientist	University of Guelph
– farmer	– who grew alfalfa for feed and seed.

To sum up quickly, it was easy to indicate the control achieved in terms of yield. When considering economics, the crops had to be analyzed for protein content, and after doing so, it could be shown which treatments were economic when percent legume in the stand and protein produced were considered. You might say—end of experiment. However, because this team was working with a farmer who produced seed, they went on to that stage and took seed yields. They found that one of the insecticides applied had a tremendous effect on seed set, when compared with the check and other treatments: a very interesting finding, and one for which we do not have the answer. However, it does open up a new area for research. Did this insecticide kill some other insect which we have not considered a problem in seed production? Did this insecticide have some effect on the legume plant that caused increased seed set?

If the latter is the case, will it affect seed set of other legumes (or other protein crops, e.g. soybean) in a similar fashion?

I maintain the team approach is correct. The original research of the above example was an indication of mission-oriented applied work. The questions raised as a result of that work could very well lead to mission-oriented basic research. So I maintain we must keep the total system in mind when doing pest control work either in research or in our extension program.

Alternate Control Methods

Much has been said this past couple of years about alternatives to chemical control of pests. This is an area of great importance. Hopefully breakthroughs will be coming.

My major concern is that much of the research in this area has not been concerned with major pest problems. There is very little sense in spending large sums of research dollars and several man-years of research working on insignificant pests. Hopefully, changes have been made in recent years to reorient the biological control programs to important problems, taking into account the total production picture.

Education

Since one of the other speakers on the program will discuss this topic, I will not develop it too far. However, if sophisticated controls are developed for the future, along with complex monitoring devices, then a tremendous educational program will be required. Will we need specialists to make the final decisions? Will our crop specialists be expected to handle the situation? Or will the grower look after the problem himself? In any case, education will be the key to success.

Equipment Engineering

One of the biggest weaknesses of our pest control programs now is in equipment. To me, this is an area that has suffered from lack of the team approach to the problem. The crop specialists, the pest control researchers, and the engineer must work hand in glove on this one. Surely if we can put a man on the moon, we can come up with better equipment to apply pesticides than those presently available.

IMPORTANCE OF FIELD CORN AS A REPRODUCTIVE SITE FOR *GLISCHROCHILUS QUADRISIGNATUS* (SAY) (COLEOPTERA : NITIDULIDAE)

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Abstract

Ears of field corn missed by harvesting machinery are the principal reproductive sites for *Glischrochilus quadrisignatus* (Say) in southwestern Ontario. The ears must have kernels and be moist to be suitable for oviposition and larval development. Burial of the ears does not prevent oviposition since infestations were found in ears buried in the fall and ears buried the following spring at depths of 3 and 6 inches in the soil.

Introduction

Glischrochilus quadrisignatus (Say) is a serious pest of several fruit and vegetable crops in southwestern Ontario. The adult beetle bores into ripe raspberries, infests kernels of sweet corn initially damaged by other insects or birds, and imbeds itself deeply in the flesh of damaged processing tomatoes between picking and delivery to the factory.

Luckmann (1963) reported that the female usually deposits eggs in the soil near decomposing plant material such as spilled grain, feed, corn ears, cob piles, and waste onion piles, where the larvae develop. A winter and early spring survey of farms in southwestern Ontario in 1969 showed that ears of field corn missed by harvesting machinery the previous fall were the principal, and often the only, source of decomposing vegetative matter available to the beetle for reproduction. This study determined the suitability of unharvested corn ears as a reproductive site and the feasibility of burying the ears to prevent or reduce oviposition by the beetle.

Materials and Methods

Unplowed corn fields were examined in the spring of 1969 and 1970. Ears found on the surface or partially buried in the soil were examined in the field and the number of adult beetles on and under the ear noted. The ears were then brought to the laboratory in plastic bags and examined for eggs and larvae. Small numbers of eggs and larvae from each infested ear were reared to the adult stage to confirm they were *G. quadrisignatus.* It was possible to continue examining ears after they had been buried by spring plowing because their location beneath the soil surface was often revealed by clumps of shoots growing from germinating kernels.

The effect of burying ears prior to the start of oviposition was examined by the burial of groups of ears in eight adjacent plots of soil, with each plot depicting a different set of conditions. There were 15 ears per plot spaced one foot apart. Included were ears with intact husks which were buried 3 and 6 inches in the soil in October and April, to simulate shallow and deep plowing in the fall and spring, and ears devoid of husks which were buried at the same levels and times. Ears with and without husks were included in the investigation to determine if the husks influenced the rate of kernel decomposition or protected the kernels against the beetle. Ears buried in the spring were left exposed on the ground all winter to be comparable to conditions in corn fields. All ears were examined before burial to ensure that no beetles were present. An ear from each of the eight plots was dug up at intervals throughout the spring and summer and examined for all forms of *G. quadrisignatus.* The soil surrounding each ear was also examined.

Results and Discussion

In 1969, frequent rains prevented the plowing of many corn fields until after mid-May. A field examined on May 15 near Harrow had numerous exposed and partially

buried ears, all of which were infested with *G. quadrisignatus*. In a sample of 10 ears, the number of adults per ear ranged from 2 to 19, and the larvae from 15 to nearly 200. Eggs were found on only four ears, but might have been present in the soil under the other six. Subsequent examination of soil in the vicinity of infested ears showed eggs were commonly laid there.

Later in May, approximately 20 fields were examined near Harrow and five near Dresden in Kent County. All fields were infested, but there were large variations in the percentages of infested ears per field and the numbers of insects per ear. Two requirements appeared necessary for reproduction, namely, that kernels be present on the cob as a source of food for adults and larvae, and that at least a portion of the ear be moist to soften the kernels.

The need to search for sprouted, buried ears reduced the numbers examined from late May to mid-August. Most of the ears which were unearthed had both adult and immature stages of the insect present, although it was not known if the infestation had been initiated before or after burial of the ears. Occasional larvae were found up to August 13, but most of the ears examined in late July and early August were badly decomposed and often devoid of endosperm.

The adequacy of corn ears as a site for abundant and extended reproduction by the beetle was most clearly shown on July 23, when an ear buried 4 inches in the soil contained 3 eggs and 647 larvae. There were 28 pupae and 11 newly developed adults in the soil nearby. Since later studies showed that newly developed adults leave the soil, it is possible that additional beetles had developed and vacated this ear.

In 1970, emphasis was placed on an earlier and more detailed study of a few fields. On April 9 and 10, all of the ears or partial ears on over 12 acres of unplowed land in two cornfields near Dresden were examined, but no beetles were found. A similar absence of infestations was noted in three fields near Harrow in early April. The first movement to old cornfields was observed near Dresden on April 15, when hundreds of beetles were in low-level flight over both plowed and unplowed land. However, the kernels were still too firm to attract the beetles and only four adults were found under the many ears inspected. By April 23, when kernels on the lower sides of ears in contact with moist soil had softened, 62% of several dozen ears examined in a field near Harrow were infested. There was a maximum of two adults per ear and no eggs had been laid. By April 27, 91% of the ears in this field were infested. In a 10-ear sample the number of adults per ear ranged from 1 to 38 with a mean of 10.8. A total of five eggs was found. The first larvae were obtained on May 4, and there were large numbers by May 11.

Burial of ears 3 inches below the soil surface did not deter oviposition since every ear examined in the spring and fall burial plots had some stage of the beetle on the ear or in the soil near the ear (Tables I and II). At the 6-inch level, however, only 80 and 53% of the ears were infested in the fall and spring burial plots, respectively. Although the data indicate that deep burial of corn ears would reduce the reproductive potential of this insect, some caution is required. The deep and shallow burial plots were close together and it is conceivable that ears buried at 3 inches would be detected first, and that some ears at the 6-inch level might escape infestation. It will be necessary to examine this further by a greater separation of plots.

Several other observations resulted from this investigation. Husks appear to decrease the rate of decomposition of the ear, but offer no protection against the beetle. Most of the larval development occurs prior to mid-June, after which the endosperm of the kernels usually becomes depleted or is unsuitable as food. Nevertheless, some ears can support a larval population until July. New adults leave the soil soon after they develop. This was shown by the large number of beetles trapped in cages placed over buried ears and the low ratio of adults to larvae in the records.

The mortality of all stages was very low. Most of the dead adults were recorded in July and appeared to be overwintering forms. Frequently they were infected by a fungus which was identified by Dr. R. P. Jaques as a species of *Beauveria* on the one occasion that diseased forms were brought to the laboratory. In the few instances that dead larvae were observed, they also had been attacked by a fungus.

Table I. Reproduction by *Glischrochilus quadrisignatus* on ears of corn buried at two depths in October 1969 and examined in 1970

Date examined	Burial depth (inches)	Numbers of each stage of *G. quadrisignatus* per ear							
		Ears with husks				Ears without husks			
		Adults	Eggs	Larvae	Pupae	Adults	Eggs	Larvae	Pupae
May 21	3	4	14	100's*	0	–	–	–	–
	6	3	10	100's*	0	–	–	–	–
May 25	3	26	137	100's*	0	34	5	100's*	0
	6	4	6	0	0	3	0	100's*	0
June 10	3	4	0	455	44	3	0	451	54
	6	35	30	357	0	0	0	82	0
June 15	3	11	0	515	62	28	0	546	165
	6	0	0	0	0	8	0	607	21
June 24	3	85	0	128	148	143	0	87	132
	6	0	18	56	0	5	0	96	59
July 9	3	30	0	0**	0**	68	0	9	24
	6	0	0	0	0	0	0	0	0
July 29	3	1	0	0	0	4	0	4	0
	6	11	0	0**	0	6	0	0**	0
August 7	3	3	0	9	3	1	0	0	0
	6	5	0	1	1	0**	0	0**	0

*Exact counts not made, often 3 to 6 larvae per kernel.
**Dead forms found, indicating an earlier infestation.

Table II. Reproduction by *Glischrochilus quadrisignatus* on ears of corn exposed on surface of ground throughout winter and buried at two depths in April 1970

Date examined	Burial depth (inches)	Numbers of each stage of *G. quadrisignatus* per ear							
		Ears with husks				Ears without husks			
		Adults	Eggs	Larvae	Pupae	Adults	Eggs	Larvae	Pupae
May 21	3	12	2	100's*	0	–	–	–	–
	6	8	10	100's*	0	–	–	–	–
May 25	3	23	15	100's*	0	3	0	100's*	0
	6	1	0	0	0	0	0	0	0
June 10	3	60	0	546	12	0	0	200	30
	6	0	0	0	0	0	0	2	0
June 15	3	3	0	559	54	1	0	138	105
	6	0	0	0	0	1	0	520	101
June 24	3	96	0	0	96	106	0	4	37
	6	0	0	0	0	0	0	1	3
July 9	3	5	0	0	1	119	0	1	7
	6	59	0	226	92	70	0	0	4
July 29	3	0**	0	0**	0	1	0	0	2
	6	17	0	0	0	0	0	0	0
August 7	3	1	0	0	0	0**	0	0	0
	6	0	0	0	0	0	0	0	0

*Exact counts not made, often 3 to 6 larvae per kernel.
**Dead forms found, indicating an earlier infestation.

It is concluded that ears of corn provide a very favorable site for reproduction by *G. quadrisignatus* and that the large numbers of beetles which occur are related to the extensive production of field corn in southwestern Ontario. The burial of corn ears prior to beetle activity did not deter oviposition and might even encourage larger infestations, since ears which remain on the surface of the soil become unsuitable as developmental sites when they are desiccated during periods of low rainfall or badly damaged by birds and rodents.

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AN APPLIED ENTOMOLOGIST LOOKS AT HIS PROFESSION

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Abstract

The profession of entomology has done a good job in providing recommendations for insect control on economic crops and livestock and has made great progress in those areas of entomology concerned with protecting the health of man. We have not, however, provided education to the public on the interesting and unique features of insects that make these animals fascinating in their own right. We have also failed to communicate to the public the true picture of the effects of pesticides and other insect control practices on the environment in which we live.

While the image of the entomological profession to the producer is good, our image to the general public is not. We must become better spokesmen for our profession to inform the public concerning the services they get for the money invested. Each of us must accept this role. In addition, we must become more knowledgeable about our environment and make sure that the pesticides we use do not create problems in it.

Professions develop because their subject matter is important to people and society is willing to pay a price to maintain experts in the field. Entomology is no exception. Insects are, and always have been, competitors for our food and fiber, and important factors in the maintenance of human health. Thus it is not surprising that society has been prepared to pay the price to develop a sufficient core of students of insects to provide advice to the public concerning these animals. The wisdom of this course has been apparent and can be documented in terms of increased food and fiber supply and the immense strides made through entomological research in the area of control of diseases transmitted by insects. One could recount all the benefits brought about by entomologists and present such an impressive list that many other professions would pale by comparison. However, despite this record of achievement the profession of entomology is struggling for support, our credibility is questioned and the society that foots the bill for our efforts is looking at us with disfavor and accusing us of leading them down a garden path strewn with pitfalls. It is apparent that at this point in time and attitude, entomology will have to shape up or face an increasing withdrawal of support.

We could examine our profession from a variety of aspects. I suggest we look at it in terms of our obligation to the society that pays our way.

The title of our symposium is applied entomology but I have great difficulty in separating applied entomology from any other kind. Society will pay only for items of value to it. Thus the efforts of our profession must benefit society and in this context we are all applied entomologists.

If we look to the obligations we have to society we can perhaps group them in four categories.

1. The first and perhaps most obvious one is an obligation for an economic return on investment. As we are all aware, insects, if permitted, would create heavy crop loss. Estimates are generally in the order of 25%. But a general total estimate is rather meaningless because the potential destruction by insects varies greatly from crop to crop and region to region. In Ontario most of our cereal crops acreage and our hay crop (until the introduction of the alfalfa weevil) have not been heavily damaged by insects. By contrast, if rigid insect control were not practiced, such crops as apples, onions, and rutabagas could not be produced. Similarly, we have the potential for economic losses due to insects in stored products, building materials, ornamental and turf production, animal production, and a variety of other areas. Thus it is our obligation as entomologists to devise methods that enable our constituents to reduce losses by insects to a minimum. This obligation is perhaps the most tangible, and the record of our profession in meeting this demand is quite good.

2. The second obligation I would cite is that associated with the role of insects in public health. Fortunately for Canadians, our direct problems in this area are not great. Malaria has occurred in some parts of Canada and western encephalitis is endemic in some areas. Although we must be alert to changes in this picture, we have a more demanding health consideration as an indirect insect problem, that is, the problems related to pesticide use–safety of applications and toxic residues in foods. It seems to me that on balance the record of the entomological profession in discharging its obligation to public health is pretty good.

3. The third obligation in my list is to the aesthetic demands of society. In this category I include such things as nuisance insects (the cluster fly and shad fly), insects that cause discomfort (blackflies and mosquitoes), and the host of colorful and interesting insects that people see and want to know something about. The entomological profession has not done very well by its clientele in satisfying this obligation. The cluster fly provokes more enquiries than perhaps any other insect and frustrates the modern housewife in her efforts to enjoy rural living. Many of our recreation sites in Ontario were barely habitable in the DDT days, and are now less so due to mosquitoes and blackflies, and these insects pose a serious problem to many communities. Our citizens are curious about many insects that they find attractive but we have not succeeded in making them sufficiently informed so that they can enjoy what they see.

4. The fourth obligation I would cite is the demand society places on us to protect our environment. This demand became increasingly vocal in recent years when it became known that some of the pesticides entomologists were recommending had adverse effects on some environmental components. This obligation is a difficult one to meet for here the benefit-risk equation has many intangibles. Here, even the tangible items in the equation are weighted differently, depending on the analyst. Because of these factors, the entomologist has been hard put to justify to society certain actions taken by his fellows in recommending certain pesticides.

The problem has been one of lack of information and inability to assess the information available. Concurrent with this, the population explosion, food shortages in some countries, and food surpluses in others have provided writers a field day, to the end that society has been influenced more by the opinions and biases of reporters than by the judgment of scientists. Society has been told that "the environment is like virginity, tempting to tamper with but once violated, it cannot be restored." Society believes that in the area of environment, the entomological profession has let them down.

If this brief review of our profession is correct, then we must accept the fact that, in the eyes of the society that pays our keep, we are meeting adequately only half of our obligations. Clearly, then, entomology as a profession must resolve to do a better job. How can this be done?

The profession of entomology has available to it three main routes by which it may discharge its obligations. These are teaching, research, and extension.

1. Teaching–Professor Chant has presented an excellent discussion on this subject but may I add a few comments. Two years ago the Entomological Society of America sponsored a symposium on the training of economic entomologists. One of the participants in the program was a vice-president of a company that is a major employer of our product. If I recall correctly, he emphasized that in terms of factual information, the graduates from our entomological programs were well prepared. He said, however, that they have three drawbacks: "They can't speak, they can't write, and they won't listen." What he was saying, I believe, is that our graduates are given the tools of the trade but little competence in how to use them to serve society. I suggest that in our educational programs we incorporate courses that will give our graduates a better appreciation of the desires and demands of society. To do this I suggest that if necessary we delete some requirements in the facts of entomology to permit our students to acquire some understanding in sociology, communications, and human ecology.

Not all of us are associated with universities and we may feel that we have no opportunity or obligation to teach. I am happy to say that my experience in Canada,

although limited, tells me that personnel in C.D.A., O.D.A.F., and industry are more than willing to present guest lectures in our university classrooms. This is wonderful and should be encouraged at every opportunity. These guest lectures bring to the classroom a broadened view and perspective of the entomological profession—a perspective much needed in our Canadian universities.

2. Research—If we were to count noses, we would find that Ontario has a good many entomologists housed in our various teaching, research, industry, and service institutions. Many of these entomologists have active research programs, in varying degrees of sophistication, for each of us recognizes that research must keep full the fountain of knowledge on which our profession depends. During the past few weeks many of us have been involved in crop protection committee meetings, preparing recommendations for 1971. This is one exercise which brings us to a tangible area of applied entomology and permits an assessment of our problems relative to our resources. Such an exercise makes it clear that, in Ontario, we have a long way to go before we have sufficient background research data to write these recommendations. We have no alternative but to present recommendations, but lack of research and justifiable caution by our committees leaves many instances where our producers will have serious economic loss if insects such as the cutworms, European corn borer, and cabbage looper exert heavy population pressures. On top of this, many of our insect control procedures on vegetable and fruit crops are very expensive and the insecticides involved may present hazards to the applicator or to the environment.

Clearly our research efforts in Ontario must be improved and they must be addressed to a much wider sphere than has heretofore been the case. Applied entomologists are, or should be, by training first-rate ecologists. Yet when we look at our insect problems in Ontario and the manner in which we try to deal with them, I believe we must conclude that we have a very limited knowledge of the ecology of our pests, and our control procedures are rather crude. However, let us not deny the fact that most of our control measures work. What I suggest is the old maxim "Know thine enemy." I believe that if we direct our research toward a better understanding of the insect in his environment we will be able to write better programs for insect control.

It goes without saying that we must research new methods of control and use every tool our ingenuity can devise. Whether these tools be biological or chemical is of no consequence. The important thing is that we meet the needs of the people we serve in each area of their concern.

In recent years we have been buffeted by a barrage of comments that the chemical pesticides we are using are causing irreparable damage to the ecosystem. As ecologists we cannot accept this. We know that ecosystems are constantly changing in response to environmental pressures and see no reason to believe that the evolutionary processes that accommodate these adjustments will suddenly stop. We must, however, evaluate the effects of our activities on the ecosystem and satisfy ourselves that we are not inducing alterations that are undesirable.

In Ontario we are moving toward a policy of spray only when needed. This is good. Going hand in hand with this is a general feeling that the integrated control approach is the one that provides the most subtle manipulation of our biological entities. I would like to see our profession adopt an ethic that says that, consistent with demands of society, we will permit natural forces optimum opportunity to adjust insect populations.

To do this will require two things:

(1) Better coordination of the total research effort in Ontario.
(2) More personnel and a different ratio of specialists in our entomological profession.

3. Extension is the third avenue through which we can discharge our obligations to society. This is really a part of our teaching program but the audience is more diverse than that encountered in the classroom. While it is true that we must have the research to extend, extension is perhaps the most vital link that we have with society, and it is the one that, in Canada, we must do the most to upgrade. By extension I am not referring

only to those specifically designated as extension specialists. Each of us has a vital role to play in seeing to it that the information developed in our research gets interpreted in meaningful terms to our constituents. We can do this in organized fashion by addressing growers and special interest groups but we can also accomplish much by preparing articles for the press and through radio and television appearances.

In the area of extension we must also be active in making sure that our legislators know of our research and are guided by it in setting policy that affects our profession.

The field of extension will be covered by other speakers during this meeting. I shall, therefore, not dwell longer on this subject. I would point out, however, that in this audience are a number of entomologists in a position to make policy regarding the total entomological activity within their institutions or agency. I would emphasize to them that in their overall plan they make sure that adequate provision is made for extension. If the society that pays the bill does not become better informed of the activities of our profession, I fear we will not have the staff necessary to meet adequately the responsibilities our profession must shoulder.

NOTES ON THE BIOLOGY AND DISTRIBUTION OF MOTHS ASSOCIATED WITH THE PITCHER PLANT IN MAINE

JOHN H. BROWER[1] and AUBURN E. BROWER[2]

Abstract

The distribution and habits of three species of moths which feed on the insectivorous pitcher plant, *Sarracenia purpurea,* in Maine are described. *Exyra rolandia* feeds on the leaves, *Papaipema appassionata* tunnels in the rhizome, and *Endothenia daeckeana* utilizes the seed capsule. The complex interrelationships which have evolved between these insects and their host plants are discussed.

Introduction

The common pitcher plant, *Sarracenia purpurea* L., is an insectivorous plant found in acid sphagnum bogs in all 16 counties in Maine. This plant's unique structural adaptations for catching insects have been described by Lloyd (1942) and others. The degree of its success can be judged from an examination of the mass of insect fragments to be found within any large pitcher. We have found remains of insects belonging to all major orders of flying insects, as well as evidence of spiders, centipedes, millipedes, and sowbugs. Judd (1959) has provided a more specific enumeration of pitcher plant victims in Ontario.

This paper deals with the insects associated with *Sarracenia purpurea.*

Pitcher Plant Insect Associates

Inquilines

The pitcher plant has evolved into an efficient insect catcher, but it also has many insects closely associated with it. Several species utilize the trap itself as a habitat. These include the mosquito, *Wyeomyia smithii* (Coquillett), whose larvae live in the liquid of the pitcher unharmed and are restricted in occurrence to the pitcher plant and its unique

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self-contained breeding pools. Similarly, the larvae of a small gnat, *Metriocnemus knabi* Coquillett, breed in the same manner. Both of these species are common in *S. purpurea* pitchers throughout the state. In Maine we have also found several species of sarcophagid larvae; the larva of a caddisfly, *Frenesia difficilis* Walker; and a freshwater isopod, *Asellus communis* Say, all living in water of pitchers. The exact method whereby the above species escape being digested is unknown.

Other insects also utilize this plant for their own purposes. A solitary wasp, *Sphex (Chlorion) harrisi* Fern., which is reported from Maine, also makes use of the old pitchers in which to build its nest. Several species of spiders build webs inside the pitchers above the water level where they intercept the plant's prey, and we have observed this habit once in Maine. Several species of mites are also reported from this plant.

Associated Moths

The pitcher plant moth, *Exyra rolandiana* Grt., is most intriguing because of its interesting habits and its close dependence on the pitcher plant. This species, limited exclusively to *S. purpurea,* was briefly described by Thaxter (1877). Jones (1921) has provided a good description of the life history and habits of the species. Although most of his observations hold true for Maine, several differences exist.

E. rolandiana flies and oviposits from late June through July. The female is reported to lay a group of eggs in the mouth of a pitcher of a single plant and the larvae then spread to various nearby pitchers of the plant. However, in Maine we believe that only a single egg is laid at a time, since we invariably have found only a single larva to a plant.

The newly hatched larvae begin to feed at once in the small pitchers where the eggs are laid. In the fall the larva moves to a fresh pitcher, usually selecting a young one which it drains by cutting a hole in the base. The larva eats away a ringing groove near the top of the pitcher, causing the top of the leaf to die and bend inward. The larva seals this door in place with silk webbing and hibernates in the chamber thus formed.

By the time the snow melts in the spring, the larvae of *E. rolandiana* are about third instar. They are a dull reddish brown and about .25 inches long. They increase rapidly in size, and having eaten the leaf in which they hibernated, move to larger leaves. They first chew a hole near the leaf base, which drains any water in the pitcher, and then enter. Jones (1907) reported that in a closely related southern species the young larvae enter the pitcher through the drainage hole. When the larva enters a new pitcher a dense silken diaphragm is spun over the mouth of the pitcher just level with the rim. This excludes rainwater from the pitcher and probably serves as a barrier to parasites and predators as well. The larva feeds on the walls, carefully eating only the inner layers of the leaf and leaving the outer cuticle. It also avoids the leaf veins which support its retreat. Judd (1957) has reported finding larvae feeding on the flowers in Ontario. When the larva reaches its full growth, about June 1 to 15, it is approximately .75 inches long and a dull carmine or brown color. The larva works its way down into the corky frass particles which have accumulated in the leaf base from its feeding activities, and thus safely buried, it constructs its cocoon. The cocoon, composed of the frass particles loosely held together with silk, is built against one side of the leaf tube. Jones (1921) reported that larvae usually seek new leaves for pupation, and spin their cocoons on the side of the leaf.

The adult emerges in 2 to 3 weeks and appears to be most common throughout July as flight records are well distributed between July 2 and July 25. There is one generation in Maine, although in extreme southern Maine, two might occur, since we have a record of a moth caught flying on September 7 in the southwest corner of the state. Adults hide and rest during the day inside the pitchers. All of the light trap catches except one (Masardis) were males, so it appears that females remain close to the host plant but males fly more strongly. The handsome moth with maroon and yellow front wings has a wingspan of just over .75 inches. Jones (1921) speculated that the coloration has evolved as a protective measure against predators while the moth is resting on the reddish-purple pitchers.

This species has been collected at 12 locations in the state, representing 7 counties

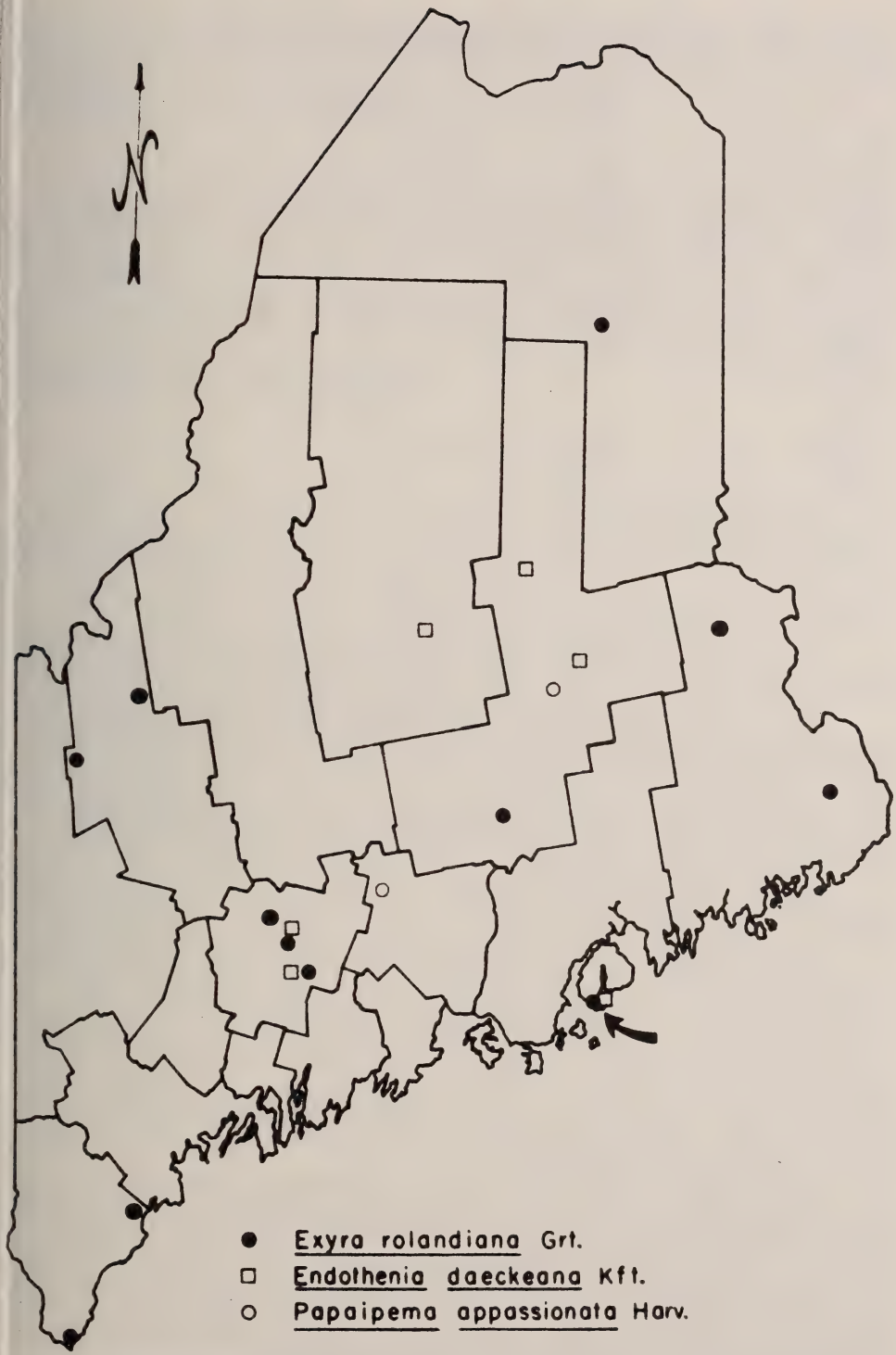

Figure 1. Map showing the distribution in Maine of the three species of moths associated with the pitcher plant, *Sarracenia purpurea* in the state.

Table 1. Distribution records for three species of pitcher plant moths in Maine listed in order from southwest to northeast

Location	*Exrya rolandiana*	*Endothenia daeckeana*	*Papaipema appassionata*
Kittery Point	Sept. 7 ♂		
Saco	July ?		
Augusta	July 9 ♂	Sept. 16	
Sidney	Reared	Reared	
Belgrade	July 2♀		
Rangeley	July 5 ♂		
Eustis	July 25♂		
Unity			Sept. 4♀
Southwest Harbor	July 18 & Reared	Reared	
Bangor	Reared		
Katahdin Iron Works		Reared	
Enfield			Sept. 18 (dead ♀
Lincoln		August 28	
Dennysville	July 17♂		
Topsfield	July 18♂		
Masardis	July 24♀		

(Figure 1). The outline map shows the recorded distribution of the species in the state. No doubt further collecting would fill in the range in northern and western Maine. We have reared this species from three of the locations, as indicated in Table 1, and contrary to some reports in the literature, rearing was simple.

Another noctuid moth, *Papaipema appassionata* Harv., attacks the pitcher plant. The larvae are typically cylindrical, with longitudinal stripes broken in the middle. The color is reddish-brown with white stripes. At maturity the larva is about 1.5 inches long.

The larvae live in burrows formed by tunneling within and feeding on the tissues of the rhizome. Workings do not extend to the pitchers. Characteristic upright aboveground tubes of debris are formed. The plant usually wilts as a result of the insects' feeding activities and probably dies the following summer. Pupation occurs about the first week in August. Bird (1903) reported that the pupa is formed outside the burrow in *S. purpurea* in New Jersey, while Jones (1908) found the pupae inside the rootstock in *S. flava* in South Carolina.

The adult has a wingspread of about 1.5 inches and has the typical *Papaipema* appearance. The forewings are yellow flecked with maroon, and have two groups of small white spots in the center of each. The adults fly late in the year and eggs are laid singly.

P. appassionata has been recorded in Maine only twice. A dead female was found September 18, 1944, in a bog at Enfield by A. E. Brower. A second specimen, also a female, in the Maine Agricultural Experiment Station collection, was taken in a light trap in Unity September 4, 1939 (Figure 1). This species is restricted to *S. purpurea* and local colonies may exist elsewhere in the state. We have watched for evidence of colonies of this species but so far have been unsuccessful. Although widespread, this species is considered uncommon, partly because it has very local distributions. It has been taken most commonly in the New Jersey pine barrens and south to the Carolinas, but the first specimen came from London, Ontario.

A third species of moth which utilizes the pitcher plant is *Endothenia daeckeana* Kft., a micro-lepidopteran. The larvae feed exclusively on pitcher plant seed heads. The moth is small, having a wingspan of only 0.5 inches, and is inconspicuous in appearance. Adults fly from late June into September, and apparently stay close to the host plant. The moth probably lays her eggs on the developing seed capsule, and the larvae bore their way into the developing ovary and hollow it out. The debris of the flower is fastened together with silk, and the pupa is formed within this mass. The species has also been collected breeding in *S. flava* in South Carolina (Jones, 1908).

Most records of *E. daeckeana* are concentrated in the middle part of the state

(Figure 1), but it undoubtedly occurs wherever the pitcher plant grows. This species has been collected from five locations in Maine, and we have also observed its feeding activities at Bangor. This last point was not included on the distribution since the specimens were not reared for a positive identification.

Discussion

The complex interrelationships which can evolve between plants and insects are clearly demonstrated by the pitcher plant and its associated insects. The plant has evolved an efficient way to capture insects, and thus utilize their nitrogen, enabling it to live in a nitrogen-deficient environment. Some insects utilize the structures of the traps as a habitat, and others use the various parts of the plant for food. Among the latter, the pitcher plant moth has evolved complex behavioral patterns which enable it to escape capture by the plant, to use the plant for food, and to utilize the traps for protection during development. Both plant and insect are particularly well adapted for their respective roles in the biotic community.

Acknowledgments

Thanks are due Dr. Harvey L. Sweetman for reading and suggesting improvements in the manuscript. The isopod and the trichopteran were kindly identified by Mr. E. B. Henson, Cincinnati, Ohio.

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IV. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND SEVENTH ANNUAL MEETING– ENTOMOLOGICAL SOCIETY OF ONTARIO

VINELAND, ONTARIO
NOVEMBER 4-6, 1970

Registration for the meetings was held from 10:30 to 12:00 a.m. in the Sands Room of the Beacon Motor Hotel, November 4.

MEETING OF OUTGOING DIRECTORS

The 1969-70 Board of Directors met on November 4, 1970, in the library of the Department of Agriculture Research Station. Those present were President S. E. Dixon, Past President J. M. Cameron, Vice-president R. L. Edwards, Directors M. G. Maw, J. H. H. Phillips, P. J. Pointing, G. E. Shewell, C. R. Sullivan and Secretary-Treasurer D. H. Pengelly.

President Dixon called the meeting to order at 11:00 a.m.

The minutes of the last Directors' meeting were accepted as circulated after the correction of the spelling of 'nominal role' and the insertion of the date of the meeting, August 29, 1969.

Motion of acceptance–J. MacB.Cameron
Seconded by M. G. Maw. Carried.

The Financial Statement for the year ending December 31, 1969; accepted on a motion by C. R. Sullivan; seconded by M. G. Maw.

The results of the mail ballot were made known to the Directors.

The report of the Editorial Board was accepted on a motion by C. R. Sullivan; seconded by J. H. H. Phillips.

The report of the committee on Student Employment by R. L. Edwards and P. S. Corbet was presented and accepted with a motion of appreciation to the committee by G. E. Shewell, seconded by P. J. Pointing.

The President's Prize Committee, M. G. Maw, chairman, presented a set of guidelines to assist in judging student papers. The Directors congratulated the committee and accepted their report on a motion by J. MacB. Cameron, seconded by C. R. Sullivan.

NEW BUSINESS

The Directors, after discussion of how to use the $500 offered by the Entomological Society of Canada for the promotion of entomology at the upper school level, recommended that the Incoming Directors establish a committee to study this and empower them to act during 1971 if an acceptable scheme is formulated. This committee is to report to the meeting in 1971.

Moved by J. H. H. Phillips
Seconded by M. G. Maw. Carried.

In 1969, President Dixon and Directors of the Society recommended that a Pesticide Regulatory Board be established in Ontario. On a motion by S. E. Dixon; seconded by J. MacB. Cameron, this recommendation was referred to the incoming Directors for appropriate action in pressing for this Board. Vote- 7 in favour; 1 opposed.

Carried.

The Directors discussed the proposal by the Entomological Society of Canada that they be empowered to collect all dues. It was moved by C. R. Sullivan; seconded by P. J. Pointing, that the Canadian Society be so empowered. Vote- 2 in favor; 6 opposed.

Motion defeated.

The Directors then recommended that the incoming Directors take this under advisement and form a committee to do an exhaustive study of, and make recommendations on, the best methods of collecting fees, and, if a mutual agreement can be reached with the Canadian Society, be empowered to implement the decisions.

Motion proposed by J. MacB. Cameron
Seconded by C. R. Sullivan. Carried.

The Directors discussed the formulation of a policy on underwriting student members of the Society attending the Annual Meeting. Motion by P. J. Pointing; seconded by C. R. Sullivan, that the registration fees be waived, was approved on a vote of 7 in favor; 1 opposed.

Carried.

The Secretary-Treasurer proposed that the Society move to recover some of the cost of mailing and handling the Proceedings by levying a charge of $1 per year and accepting payment for up to 5 years in advance.

Moved by J. MacB. Cameron
Seconded by C. R. Sullivan. Carried.

The proposal that an Accumulation Index of the Proceedings be published to cover the period 1938 to 1969 inclusive, was approved on a motion by R. L. Edwards; seconded by C. R. Sullivan. In that a start has been made, this was left in the hands of the Secretary-Tresaurer.

It was proposed that the Society entertain its Honored Fellows at the Annual Meeting and waive registration, reception and banquet fees.

Moved by P. J. Pointing
Seconded by G. E. Shewell. Carried.

No further business. The Secretary-Treasurer was instructed to compile the Agenda for the Annual Meeting.

Motion for adjournment by M. G. Maw at 1:10 p.m.

Registration continued from 1:00 to 3:00 p.m. in the Lower Hall of the Beacon Motor Hotel.

ANNUAL MEETING

The 107th Annual Meeting of the Society was held in the Sands Room of the Beacon Motor Hotel. The opening session began at 1:30 p.m., November 4, under the chairmanship of President S. E. Dixon. An address of welcome was given by Dr. J. A. Archibald, Director of the Horticultural Research Institute of Ontario, Vineland Station. An address by President Dixon was followed by remarks and announcements pertaining to the arrangements for the upcoming sessions.

Two Invitation Papers were presented at a session starting at 2:15 p.m.

CHIBA, M. (Vineland Station). Can an analytical chemist contribute to applied entomology?

JAQUES, R. P. (Research Station, Harrow). Control of cabbage insects by viruses.

After a recess, four papers were presented in a session beginning at 3:30 p.m. under the chairmanship of D. C. Herne.

FRIEND, W. G. (University of Toronto). Rearing of the tsetse fly under artificial conditions.

Because of its low reproductive potential the tsetse fly, *Glossina morsitans,* appears to be susceptible to control by the sterile insect release method. Before this method can be applied, an inexpensive technique for rearing very large numbers of this insect must be developed. This paper describes some attempts to rear this insect using modified vertebrate blood as their food. Various natural and artificial membranes were tested for their ability to induce feeding.

GOLINI, V. I. and D. M. DAVIES (McMaster University, Hamilton). Upwind orientation of adult female *Simulium venustum* Say (Diptera : Simulidae) in Algonquin Park, Ontario.

MORRIS, G. K. (Erindale College, University of Toronto). Stridulation mechanisms in *Metrioptera sphagnorum.*

Photographic and oscilloscope studies of sound production by a shield-backed grasshopper, *Metrioptera sphagnorum,* indicated major trains of sound pulses coincide with wing closures. This insect's stridulation consists of alternating audio and ultrasonic segments. The audio is produced by the passage of a scraper over the *distal half* of a toothed ridge (file); the ultrasonic component was shown to coincide with tooth-strikes on the proximal half of the file. Photographic analysis leads to the conclusion that for the ultrasonic pulse trains the insect strikes a few, widely separated rather than consecutive, file teeth.

TROTTIER, R. (Vineland Station). Resident and migratory populations of *Anax junius* (Odonata : Aeschnidae) in Ontario.

Field studies, at eutrophic ponds near Toronto, showed that in Canada populations of *A. junius* were not only maintained by migrants each year (Walker, 1958) but also by residents. Two distinct populations were found, a summer (migratory) population which developed from oviposition to emergence in approximately three months from June to September, and an overwintering (resident) population which overwinters as half-grown larvae and developed in

approximately 11 months from mid-July of one calendar year to the end of June of the next year.

Members of the Society attended a smoker in the Sands Room, Beacon Motor Hotel, beginning at 7:30 p.m., November 4. During the evening Dr. W. A. Crich of Grimsby gave a talk on color photography of insects and other nature subjects, illustrated with slides.

On Thursday, November 5, at a session beginning at 9:15 a.m. under the chairmanship of J. M. Cameron, four papers were presented.

NIGAM, P. C. (Chemical Control Research Institute, Department of Fisheries and Forestry, Ottawa). Contact residual and systemic toxicity of 27 insecticides against the spruce budworm.

Twenty-seven insecticides belonging to the chlorinated hydrocarbon, organophosphorus and carbamate group were tested against the spruce budworm (*Choristoneura fumiferana* (Clem.). Zectran^{R} and Matacil^{R} were the most toxic compounds against the 5th instar spruce budworm larvae, and Baygon^{R} was the least effective. Bayer 77488 and Gardona^{R} appear to be more promising than Zectran and Matacil when the whole forest ecosystem is considered. Their toxicity to mammals, birds and fish is many times less than Zectran^{R} and Matacil^{R}. The paper discusses the results of contact, systemic and residual toxicity of these insecticides against the larvae, and correlates their selective toxicity in the ecosystem.

THOMAS, J. B. and C. R. SULLIVAN (Forest Research Laboratory, Sault Ste. Marie). Cold-hardiness of larvae of the European elm bark beetle, *Scolytus multistriatus* (Marsh).

The European elm bark beetle, *Scolytus multistriatus* (Marsham), is the principal vector of Dutch elm disease, *Ceratocystus ulmi* (Buis.) C. Moreau, in southwestern and parts of eastern Ontario. An investigation of the tolerance of this beetle to low temperature was started to determine if it might survive in central and northern Ontario. Preliminary results of laboratory tests indicate that this species might survive winter temperatures in certain areas particularly with some protection from snow cover.

FAST, P. G. (Forest Research Laboratory, Sault Ste. Marie). Recent developments in the study of *Bacillus thuringiensis* δ–endotoxin.

ANGUS, T. A. (Forest Research Laboratory, Sault Ste. Marie). Recent developments in the study of δ–endotoxin.

After a recess, the sessions were resumed at 10:30 a.m. under the chairmanship of S. E. Dixon, with five papers presented by students in competition for the President's Prize.

THOMSON, A. J. (McMaster University, Hamilton). The study of the soil atmosphere in relation to entomological problems.

Methods for collecting and analyzing samples of the soil atmosphere are discussed, as are methods of producing atmospheres of known composition in the laboratory. Field studies and laboratory experiments are discussed in relation to the biology of *Pollenia rudis* (Fabr.) (Diptera: Calliphoridae), and its host earthworms, especially *Eisenia rosea* (Sav.) (Oligochaeta: Lumbricidae).

YAHNKE, W. (University of Western Ontario, London). Factors affecting egg production and hibernation response in *Pollenia rudis* Fab.

This paper constitutes a progress report of a study aimed at continual rearing of *Pollenia rudis* Fab. under controlled laboratory conditions. Methods of obtaining limited success in the rearing of *Pollenia rudis* Fab. and observations on all stages of flies so reared were discussed.

GROSS, H. P. (Queen's University, Kingston). Introductory studies on the use of radiation in the control of blackflies.

These preliminary investigations of effects of radiation on blackflies were undertaken with a view to developing methods of control based on the "sterile-male" technique. Mature blackfly larvae were irradiated at various doses (from 2 kR-32 kR) and allowed to complete development in aerated stream water in the laboratory. The larvae were preponderantly *Simulium venustum* Say as determined by inspection of pupae and adults. It was found that percentage pupation following irradiation remained at a fairly constant level (about 93%), whereas emergence from pupae dropped from 54% at 2 kR to 0% at 28 kR. Though varying widely, the percentage emergence of the controls averaged 47%. Adults inspected for radiation damage appeared unchanged at the lower doses, e.g. 2 kR to 8 kR, as compared to controls. At higher doses (e.g. 16 kR) the abdominal cavities usually showed a notable decrease in stored fat bodies. As well, the anterior two-thirds of the abdomens were largely devoid of internal organs, many of which, including the ovaries and testes, were found in a degenerate condition at the posterior tip.

VANDER HOEK, G. (University of Western Ontario, London). Development of the parasite *Aphidius pulcher* in the pea aphid *Acryrthosiphon pisum.*

SCOTT, N. (University of Waterloo). Histological observations on the larval fatbody of *Protophormia terrae-novae* (Desv.) throughout pupation, using water-soluble glycol-methacrylate.

In the first 40 hours following pupation, the cells of the fat body undergo loss of the cellular membrane, coalescence of their inclusions, condensation of their internal reticular network and release of the original cellular content into the hemolymph. The tissue components in the following 80 hours are partially depleted and leukocytes in the tissue proliferate. One hundred and fifty hours after pupation, tracheation of the tissue and formation of new cellular membranes occur, and by the time of emergence of the imago at 172 hours after pupation new discrete fat body cells, the remnants of the original larval fat body, remain in the hemocoel.

In the afternoon of November 5, starting at 1:15 p.m., under the chairmanship of D. G. Peterson, a symposium was held on the subject "Applied Entomology, present and future"; the following three papers being presented:

CHANT, D. A. (University of Toronto). Educational requirements of applied entomologists.

McEWEN, F. L. (Ontario Agricultural College, Guelph). An applied entomologist looks at his profession.

BEELER, B. E. (Soils and Crops Branch, Ontario Department of Agriculture and Food, Toronto). What does agriculture expect of applied entomology?

After a recess, a session was held starting at 4:00 p.m., under the chairmanship of J. A. George, the following three papers being presented:

BEREZA, K. (University of Guelph). The status and management of the alfalfa weevil in Ontario.

The alfalfa weevil *(Hypera postica)* became established in Ontario along lakes Erie and Ontario about 1966. Since then it has spread into all of southwestern Ontario (40 counties). Damage at the economic level first appeared in 1969 in seven counties and in some twenty counties closest to the lakes in 1970.

The key to the pest's rapid spread and damaging capability is the egg-laying capacity of the adult. Each female will lay an average of 500 eggs in May and the resultant larvae quickly devour the first cut alfalfa in June with appreciable damage resulting to the regrowth if a substantial carryover of the larvae occurs. Adult feeding is not significant.

A control measure is necessary when 50% of the alfalfa leaves show feeding damage. Cutting the alfalfa at or prior to this damage index is an effective method of control if the alfalfa is sufficiently mature, otherwise an insecticide must be resorted to. Insecticides may also have to be used on the regrowth if damage is evident. The long-term hope for the control of the alfalfa weevil are parasites. Now present in Ontario are Eulophid, Braconid, and Ichneumonid species which parasitize both the larval and adult stages of the weevil.

STEVENSON, A. B. (Vineland Station). The incidence and severity of bird damage to grapes in the Niagara Peninsula of Ontario.

McEWEN, F. L., H. W. GOBLE, C. F. FILMAN and L. V. EDGINGTON (University of Guelph). Onion maggot and onion smut and control.

On Thursday evening, November 5, a reception and banquet were held in the Shore Room at 6:30 p.m. The President's Prize was presented. The guest speaker was Dr. E. H. Smith, Director, Co-operative Extension, New York State, Cornell University.

On Friday, November 6, starting at 9:15 a.m., a session was held under the chairmanship of D. C. Herne; the following papers being presented:

FISHER, R. W. (Vineland Station). Problems associated with pesticide application in large apple trees in Ontario.

HERNE, D. C. (Vineland Station). Organophosphorus resistance in the 2-spotted mite.

PESCHKEN, D. and P. HARRIS (Entomology Research Laboratory, Belleville). Adaptation of *Chrysolina quadrigemina* (Chrysomelidae : Coleoptera) from a Mediterranean to a Canadian winter.

Colonies of *C. quadrigemina,* originating in Loftus, California, were released on British Columbia rangeland in 1951. Eighteen years after the release, stock from B.C. and California were compared in the laboratory. Results indicated that the B.C. beetles lay comparatively more eggs in the fall. Low temperatures in the fall prevent the eggs from emerging and since they are the stage most resistant to low temperatures, many probably survive the winter. Thus the beetles in B.C. probably overwinter largely in the egg stage instead of breeding throughout the winter as they do in a Mediterranean climate.

MAW, M. G. (Entomology Research Laboratory, Belleville). Manipulation of oviposition sites of mosquitoes in the field.

Capric (decanoic) acid when added to pool water at the rate of 150 to 300 ppm not only acts initially as a larvicide but also in time causes the pools to be preferred oviposition sites by the mosquitoes, *Culex pipiens* and *Culex restuans.* Preference shown by the mosquitoes for these pools for oviposition can be assessed by reference to a five-day period in August 1970, when

3,245 egg rafts were laid in 11 treated pools, while 10 egg rafts were laid in a total of 21 adjacent but untreated ones.

DUSTAN, G. G. and J. H. H. PHILLIPS (Vineland Station). Forty years of bait-trapping the oriental fruit moth in the Niagara Peninsula.

DONDALE, C. (Entomology Research Laboratory, Belleville). The spiders of Heasman's field.

WALLACE, D. R. and S. G. SMITH (Forest Research Laboratory, Sault Ste. Marie). Sex determination in a pine sawfly, *Neodiprion nigroscutum* Middleton (Hymenoptera : Diprionidae).

After several generations of inbreeding, diploid males in addition to parthenogenetic haploid males were found in a laboratory population of *Neodiprion nigroscutum,* a widely distributed but rarely abundant sawfly on jack pine, *Pinus banksiana* Lamb. The diploid males occur among the offspring of mated females and not in the progeny of virgin females, the latter consisting solely of haploid males. Diploid males are usually about 30% heavier than haploid males at 24 hours after cocoon spinning. The haploid males mate readily, but only one diploid male out of about 100 tested has achieved a successful copulation as indicated by the presence of females among the progeny. The females produced were triploid. Although this type of sex determination has been known for 45 years in the Apocrita (a braconid wasp), this is the first time it has been recorded in the Symphyta. It has not yet been demonstrated in related species or in a wild population.

After a recess, the Annual Business Meeting of the Entomological Society of Ontario was held, starting at 11:15 a.m. In the afternoon, a meeting of the incoming Board of Directors was held at 12:30 p.m. in the Sands Room of the Beacon Motor Hotel.

ANNUAL BUSINESS MEETING

The Annual Business Meeting was held in the Sands Room of the Beacon Motor Hotel, Vineland Station, on November 6, 1970.

The meeting, attended by 39 members, was called to order by President Dixon at 11:15 a.m. A minute of silence was observed in memory of our members and colleagues who passed away during the past year.

H. A. U. Monro	– London
G. Wishart	– Belleville
G. W. Stehr	– Sault Ste. Marie

The minutes of the 106th Annual meeting held at Guelph were circulated to the membership. It was moved by the Secretary-Treasurer that these be accepted. Seconded by T. A. Angus. Motion carried.

The Financial Report for the year ending December 31, 1969, was accepted on a motion by P. G. Fast, seconded by C. R. Sullivan. (See Proceedings, vol. 100 (1969), page 243.)

It was moved by W. C. Allan, seconded by H. J. Teskey, that the Interim Financial Statement to November 1, 1970, be accepted. Attention was directed to the postage expense which this year amounted to over $900. Motion carried. (See Appendix I for complete statement for 1970.)

The results of the mail ballot showed that 171 ballots were returned and the Directors for the year 1970-71 are:

R. E. Bellamy	P. J. Pointing
R. L. Edwards	C. R. Sullivan
J. A. George	H. J. Teskey
R. J. McClanahan	

REPORT OF THE EDITORIAL COMMITTEE

Volume 100 of the Proceedings has been printed and includes four reviews of infestations of insects and other pests, two invitation papers, twenty-two submitted papers and the Proceedings of the 106th annual meeting held at Guelph, Ontario, August 25-29, 1969.

For the first time, an abstract of each published article is included, before the main body of the article, to be used directly by the editors of "Biological Abstracts".

Members of the Society and other entomologists are encouraged to submit papers on all branches of entomology for Volume 101, in particular reviews of infestations and studies of insects in Ontario. Authors are requested to include an "Abstract" in the manuscript between the name and address of the author and the main body of the article, as in Volume 100, for use by "Biological Abstracts". Prepare papers according to the guide on the inside back cover of Volume 100, 1969, and submit them by January 15, 1971.

W. W. Judd,
Editor.

Acceptance moved by J. Mac B. Cameron, seconded by J. H. H. Phillips. Carried.

LIBRARIAN'S REPORT

The details connected with the transfer of our holdings have been completed and the Library is now operating smoothly. It is evident that the decision to integrate our holdings with those of the Zoology "QL" section of the main University Library was a wise move. Journals and holdings which were short and had many blanks are now well represented. In many instances, the University has obtained the missing issues and is prepared to bind those volumes that are used extensively as references. All journals are of course on Library Loan and are available at short notice to any Society member. Many of our old books and journals have been placed in the Rare Book Section and are now being properly cared for as to humidity and heat requirements.

At the request of the Exchange Committee, those journals which were received as duplicates, because subscriptions were in force from other sources, have been dropped from our Exchange List and this has resulted in quite some saving to the Canadian Society.

The work of preparing a bibliographic record of all QL holdings is progressing and we expect that it will be possible to issue current catalogs for all holdings in the near future.

Publications which are placed in the University Library are stamped, when cataloged so that credit is given to the Entomological Society's Library.

All members are encouraged to use the entire facilities of the University Library which are available seven days a week from 9:00 a.m. until 2:00 a.m. daily.

W. C. Allan,
Librarian.

The reduction of exchanges from over 100 to 37 was questioned by J. Mac B. Cameron because it would be most unfortunate to break runs of journals. W. C. Allan reported that only duplicated journals were discontinued and no further deletions were anticipated. H. J. Teskey reported that the Entomological Society of Canada was considering ways to supply the Canadian Entomologist to under-developed countries. The librarian stated that this has been a main consideration of the Ontario Society for many years.

It was moved by W. C. Allan that his report be accepted, seconded by P. J. Pointing. Carried.

REPORT OF THE COMMITTEE INVESTIGATING EMPLOYMENT PROBLEMS OF ENTOMOLOGISTS IN ONTARIO

INTRODUCTION

The question of employment opportunities for entomologists in Ontario was raised by a graduate student at the Annual Meeting of the Entomological Society of Ontario, held at the University of Guelph in August 1969. A committee consisting of Professor R. L. Edwards (Chairman) and Dr. P. S. Corbet was struck, and given as its terms of reference, "to investigate and advise on the present and future problems of employment for students in Entomology".

METHODS

The investigation consisted of undertaking two surveys aimed at finding the relationship between supply and demand of entomologists, at the present time, and in the immediate future. One survey sought to determine the probable supply of entomologists from the graduate schools of Ontario universities; the other survey sought to assess the actual and planned demand for entomologists by the main employers in Ontario, i.e. Federal Government agencies, provincial universities, Provincial Government agencies, and industry.

Although in theory it is difficult to give a precise definition of what is meant by the term entomologist, in practice this did not create a serious problem, and the errors introduced into the results through differences in interpretation are probably minimal.

To assess the number of graduate students in entomology, a telephone call was made to every university in Ontario, and the number of graduate students who were considered to fall within the definition of an entomologist was determined by discussion with the appropriate official. This was usually the Chairman of the Biology Department or the Dean of Graduate Studies. Initially an attempt was also made to determine the expected year of graduation of each graduate student, but it soon became obvious that this is influenced by so many unknown factors that the information would be difficult to collect, and the attempt was abandoned.

Information on the numbers of entomologists employed by Ontario universities and any planned additions for the coming year was also obtained during the telephone survey. Information on the employment of entomologists in industry and government service was obtained by means of a questionnaire. This asked for information on the numbers and kinds of posts in which an entomologist could be employed, and the number of people recruited, in each of the years 1969, 1970, and 1971.

In conducting the survey, no special attempt was made to assess the situation with regard to the position of Post-Doctorate Fellows. These Fellowships tend to vary in number from year to year, and

are often only fortuitously awarded to entomologists. Moreover, while each Fellowship would represent a "demand" factor, the person to whom it is awarded must be considered a "supply" factor, as he is generally actively seeking a more permanent position. For the purposes of this survey therefore, both the Fellows and the Fellowships were considered to be in limbo, somewhere between supply and demand, and were assumed to cancel each other out.

RESULTS

The results of the surveys, which are given in detail in Tables 1 and 2, are summarized below:–

Number of graduate students in entomology in Ontario Universities

M.Sc.	33
Ph.D.	21
Total	54

Number of existing positions for entomologists in Ontario

	1969	1970	1971
Federal Government Service	120	115	115
Ontario Government Service	8	8	4
Industry	2	2	2
Ontario Universities	38	40	40
TOTALS	168	165	161

SUMMARY AND CONCLUSIONS

Although the survey was superficial in nature, and omitted a number of questions that would probably have been included in a more searching sociological study, it produced a 100% response from those who were contacted, and probably gives a very good overall picture of the employment situation for entomologists at the present time.

If the average time spent on an M.Sc. program is assumed to be two years, and the time spent on a Ph.D. program is four years, and if there is no major change in the graduate studies programs of Ontario universities, we can expect an average output of approximately 21 postgraduate students with training in entomology in each of the next few years. In theory, 16 of these may have an M.Sc. degree, and 5 may have a Ph.D. degree; but in practice, some of these students will fail, and some of the M.Sc. students will continue into the Ph.D. program after completing their M.Sc. work. The numbers of postgraduate students getting a doctorate degree will therefore be somewhat higher, and the numbers with masters degrees will be considerably lower.

At the same time, if it is assumed that the average rate of turnover in the existing positions is 3% per annum, we can expect vacancies for entomologists to become available at the rate of approximately 5 per year. However, the total number of existing positions for entomologists is expected to decline at about the same rate, from 168 in 1969 to a projected 161 in 1971. Moreover, none of the potential employers has definite plans for the establishment of new positions in the immediate future.

The obvious conclusion that can be reached on the basis of these figures is that unless there is a sharp increase in the demand for entomologists, their opportunities for employment in universities, industry and government service do not look too promising for the next few years. In reaching this conclusion, however, it should not be assumed that this situation is any worse than that which exists for other types of biologists. The surveys provided no evidence on this aspect.

Finally, one must not lose sight of the limitations of the survey. Undoubtedly, some of the graduate students in Ontario universities are from other provinces and other countries; if they plan to return to their homes on graduation, they will not be seeking employment in Ontario. Again, the surveys provide us with no information on the numbers of Ontario citizens who are currently undertaking graduate work in other provinces, or other countries, and who plan to seek employment in Ontario when they graduate. This information could only be obtained by a much more comprehensive survey which would seem to be outside the terms of reference of the present committee.

Roy L. Edwards, (Chairman)
P. S. Corbet

Table 1. Numbers of graduate students in entomology at Ontario universities in 1970-71.

	M.Sc.	Ph.D.
Brock	0	0
Carleton	4	4
Guelph	4	2
Lakehead	0	0
Laurentian	1	0
McMaster	3	1
Ottawa	0	0
Queen's	4	6
Toronto	3	4
Trent	0	0
Waterloo	4	4
Waterloo Lutheran	0	0
Western	7	0
Windsor	0	0
York	3	0
TOTALS	33	21

Table 2. The number of existing positions for entomologists in Ontario.

	1969	1970	1971
Canada Department of Agriculture			
Research Scientists	83	83	83
Canada Department of Fisheries & Forestry			
Fisheries Research Board			
Research Scientist	1	1	1
Scientific Support	1	1	1
Canadian Forestry Service			
Research Scientist	25	20	20
Research Officer	5	5	5
Forestry Officer	5	5	5
Department of National Defence	0	0	0
Canadian Wildlife Service	0	0	0
National Research Council	0	0	0
Science Council of Canada	0	0	0
Subtotals	120	115	115
Ontario Water Resources Commission			
Biological Surveys	5	5	1
Ontario Department of Lands and Forests			
Pest Control	2	2	2
Ontario Department of Agriculture and Food			
Agricultural Specialist	1	1	1
Subtotals	8	8	4
Industry			
Cyanamid of Canada			
Field Technical Service	2	2	2
Subtotal	2	2	2

Table 2 (Continued)

Universities				
Brock		0	0	0
Carleton		4	4	4
Guelph		11	12	12
Lakehead		3	3	3
Laurentian		2	2	2
McMaster		1	1	1
Ottawa		0	0	0
Queens		4	4	4
Toronto		5	6	6
Trent		1	1	1
Waterloo		3	3	3
Waterloo Lutheran		0	0	0
Western		3	3	3
Windsor		0	0	0
York		1	1	1
	Subtotals	38	40	40
	Grand Total	168	165	161

A motion for acceptance of this report, made by R. W. Fisher, seconded by R. J. McClanahan, was passed unanimously.

The Secretary-Treasurer presented items of information discussed by the Directors and outlined briefly the decisions reached. These are to be found in the minutes of the meeting of the Directors.

REPORT FROM ESO REPRESENTATIVE TO THE ESC COMMITTEE ON COMMON NAMES OF INSECTS

The chairmanship of the ESC Committee changed in September 1969, when Dr. D. C. Eidt relinquished the post to take up new duties in the Society and was replaced by Mr. H. B. Wressell. Mr. Wressell's appointment to the ESC Committee is as one of the representatives of the ESC membership-at-large, rather than as a representative of a regional society. It is appropriate that the new chairman is the one Canadian member of the Common Names Committee of the Entomological Society of America.

Efforts continue to be made to secure with the ESA an agreeable basis for forming a truly joint committee for the adjudication of common names for North American insects.

Proposals for 7 additional common names were examined by the committee during the past year.

Glenn B. Wiggins
ESO Representative

NEW BUSINESS

G. E. Shewell proposed that a member of the Society should be able to apply for an honorary membership upon retirement. After some discussion it was moved by T. A. Angus, and seconded by P. J. Pointing that this be studied by the Directors. Carried.

W. F. Baldwin moved that the Directors consider raising the honorarium of the Secretary-Treasurer to $200 per year. The motion, seconded by J. Mac B. Cameron, passed with one negative vote.

PLACE OF ANNUAL MEETING

G. E. Shewell extended an invitation to the Society to meet in Ottawa in 1971. A second invitation was presented by W. F. Baldwin for the Society to meet at Chalk River. After some discussion it was moved by W. C. Allan, seconded by P. G. Fast that we accept the invitation to meet in Ottawa. Vote 16 in favor, 10 opposed. Motion carried.

W. F. Baldwin reported that the Society would be most welcome to come any time and extended the invitation to 1972. Although our constitution does not permit us to accept at this time, we are pleased to have the proposal extended to a future date.

REPORT OF RESOLUTIONS COMMITTEE

BE IT RESOLVED:

(1) that the Society through the Secretary-Treasurer extend thanks to Dr. J. A. Archibald for making available to us the facilities of the Vineland Station.

(2) that the Society hereby express appreciation to the Program and Local Committee, headed by G. G. Dustan and J. H. H. Phillips, for the fine job which they have done to make this meeting so successful.

(3) that those responsible for acquiring the services of W. A. Crich and E. H. Smith be congratulated and accept our thanks.

(4) that the members of the Society extend their thanks to D. G. Peterson, D. A. Chant, F. L. McEwen, and B. E. Beeler for the informative and interesting manner in which they conducted the Symposium.

(5) that the members hereby express their thanks to all competitors who took part in the President's Prize Competition and that our thanks be extended to the judges, T. A. Angus, R. L. Edwards, and M. G. Maw.

W. C. Allan, Chairman
W. F. Baldwin

A motion for acceptance, made by W. C. Allan, was seconded by G. E. Shewell. Carried.

Appointment of Auditors

It was moved by J. Mac B. Cameron, seconded by P. G. Fast, that Saunders and Wright be re-appointed. Motion carried.

As there was no further business a motion for adjournment was made by R. W. Fisher at 12:25 p.m.

MEETING OF INCOMING DIRECTORS

The meeting of incoming Directors for 1970-1971 was held in the Sands Room of the Beacon Motor Hotel, Vineland, on November 6, 1970.

Present were S. E. Dixon, R. L. Edwards, J. A. George, R. J. McClanahan, P. J. Pointing, C. R. Sullivan, H. J. Teskey and the Secretary-Treasurer.

The meeting was called to order by President Dixon at 12:30 p.m.

Nominations were opened for the position of President. P. J. Pointing nominated C. R. Sullivan. This was seconded by J. A. George. Nominations were closed on a motion by H. J. Teskey.

Past President Dixon turned the chair over to President Sullivan.

Nominations for Vice-President were opened. J. A. George declined nomination because of a two-year absence to become effective in midsummer 1971. It was moved by S. E. Dixon, seconded by P. J. Pointing that R. L. Edwards be Vice-President. There were no further nominations.

The Secretary-Treasurer was re-appointed on a motion by H. J. Teskey, seconded by J. A. George.

The minutes of the last meeting of the Directors were read by the Secretary-Treasurer and accepted on a motion by R. L. Edwards, seconded by P. J. Pointing.

Appointment of Committees

The Library Committee was thought to have fulfilled its obligations very commendably. It was agreed that the role of Librarian should be filled by someone at Guelph if possible, and should W. C. Allan not accept this appointment, the Past President and the Secretary-Treasurer would name an alternative. It was moved by S. E. Dixon, seconded by P. J. Pointing, that a librarian be appointed.

Carried.

Appointment of Editor

The Directors hoped W. W. Judd would continue with his good work and it was moved by R. J. McClanahan, seconded by J. A. George, that the present editor be asked to continue.

Motion Carried.

It was moved by H. J. Teskey, seconded by J. A. George that the editorial committee of J. E. Steele and G. McLeod be re-appointed. Motion Carried.

Director-at-large to the Canadian Society

C. R. Sullivan, appointed for a two-year term in 1969, was asked to continue on a motion by H. J. Teskey, seconded by R. L. Edwards. Motion Carried.

Nominating Committee

This committee consists of the Past President, the Secretary-Treasurer and a chairman named by the Directors. W. F. Baldwin was named on a motion by H. J. Teskey, seconded by J. A. George. If W. F. Baldwin is unable to accept, D. M. Davies is to be asked. Motion Carried.

Appointment of Scrutineers

It was moved by S. E. Dixon, seconded by P. J. Pointing, that two members at Guelph, R. Wright and H. W. Goble, be named. Motion Carried.

Representative to the Committee for Electing Fellows to the Entomological Society of Canada

Last year, the Directors ruled that this duty should fall to the President of our Society. It was moved by S. E. Dixon, seconded by P. J. Pointing, that this continue. Motion Carried.

Committee on President's Prize

It was moved by R. L. Edwards, seconded by R. J. McClanahan that M. G. Maw be asked to chair this committee, consisting of the President and the Secretary-Treasurer, to investigate and establish a feedback system of constructive criticism for the student competitors. Motion Carried.

New Business

A nomination for Fellowship in the Ontario Society was received and passed by the Directors. This will be placed on a ballot for your consideration in 1971.

The Directors were charged with establishing a committee to investigate and implement a system to use effectively $500 offered by the Canadian Society for promoting entomology in the Ontario schools. P. J. Pointing accepted the chairmanship of this committee of one with power to add further members. If you have any bright ideas, he would appreciate hearing them. Send c/o Department of Zoology, University of Toronto.

Committee on the Collection of Dues

On a motion by J. A. George, seconded by R. J. McClanahan, a committee consisting of the President, C. R. Sullivan, J. MacB. Cameron, and the Secretary-Treasurer was formed to investigate and report to the next meeting. The committee is empowered to act if a working system can be established.

Pesticide Regulatory Board

The Directors named S. E. Dixon a committee of one, with power to add, to continue pressing for the establishment of such a Board.

Fees for Auditors

On a motion by D. H. Pengelly, seconded by R. J. McClanahan, the gratuity to the Auditor was raised to $10.

Honorarium to Secretary-Treasurer

As recommended by the Annual Meeting, the Directors approved the establishing of the honorarium at $200 per year on motion by P. J. Pointing, seconded by H. J. Teskey.

There was no further business. The motion for adjournment by H. J. Teskey was approved at 2:25 p.m.

APPENDIX I

ENTOMOLOGICAL SOCIETY OF ONTARIO

FINANCIAL STATEMENT FOR YEAR ENDING DECEMBER 31, 1970

RECEIPTS		DISBURSEMENTS	
Dues Received	$2,239.43	Dues to Ottawa	$1,866.00
Exchange included	4.95	Exchange on cheques	11.10
Premium (U.S.)	19.48	Stationery	4.99
Sale of Proceedings	93.90	Printing	85.36
Ontario Government Grant	300.00	Postage	916.70
Bank Interest	276.12	Express	39.65
Bond Interest	18.00	Annual Meeting	
Receipts		Cash Advance	50.00
Annual Meeting	525.00	Banquet and Smoker	540.91
Cash Advance	50.00	President's Prize	50.00
	3,526.88	Tickets etc.	41.65
Bank Balance		Secretarial Assistance	25.00
Jan. 1, 1970	4,643.64	Auditors	10.00
	8,170.52	Honorarium (Secy-Treas.)	150.00
Bonds	400.00		3,791.36
Investment Certificate	726.41	Bank Balance	
	$9,296.93	Dec. 31, 1970	5,072.07
			8,863.43
		Outstanding cheques	692.91
			8,170.52
		Bonds	400.00
		Investment Certificate	726.41
			$9,296.93

Audited and found to be correct:

B. E. Saunders

(signed)

G. C. Marcotte
February 2, 1971

D. H. Pengelly
Secretary-Treasurer

APPENDIX II

PRESIDENT'S PRIZE

Five papers were presented by university students at the 107th Annual Meeting in the tenth annual competition for the President's Prize (see names of students and titles of papers above). The judges were T. A. Angus, R. L. Edwards and M. G. Maw. The prize was awarded to Harm P. Gross, Queen's University.

Harm P. Gross was born in Sudbury in 1950. He completed his high school education in Chelmsford and entered Queen's University in 1968, where he is presently registered in the third year of the Honors Biology course. One of his interests is blackflies. He spent the summer of 1969 at Baie Comeau, Quebec, studying the biology and control of blackflies, and the summer of 1970 on a joint Queen's University-C.R.N.L. blackfly project at Chalk River.

V. IN MEMORIAM

HECTOR ALEXANDER URQUHART MONRO
1906 – 1970

Hector Monro was born on April 1, 1906, at Leigh-on-Sea, Essex, England, and died in London, Ontario, on June 1, 1970, after a lengthy illness. Dr. Monro came to Canada in 1928 and after a short time took up studies in Entomology at MacDonald College of McGill University in St. Anne de Bellevue, Quebec. He graduated with a B.S.A. in 1933, an M.Sc. in 1935, and a Ph.D. in 1959. During his undergraduate training he became interested in plant quarantine work and was employed by the Plant Protection Division of the Canada Department of Agriculture to organize and develop research on plant quarantine problems at the Dominion Fumigation Station in Montreal. He was officer-in-charge of this station up to 1950 and during this time he did a great deal of the pioneering work on plant quarantine problems and ship fumigation.

Dr. Monro's outstanding abilities as an entomologist and plant quarantine specialist were soon recognized, and in 1950 he was transferred to the Science Service Laboratory in London, Ontario, to devote his full time to research on fumigants and the development of new methods of insect control. In 1952 when foot and mouth disease was accidentally introduced into Western Canada from Europe, Dr. Monro was sent to Europe by the Canadian Government to investigate the occurrence and extent of the disease and to study precautions, methods of prevention and control. He became a world authority on fumigation and the use of fumigants for insect control; in 1958 he was asked by the Food and Agriculture Organization of the United Nations to write a manual on the subject. This manual was published in 1961. It was enthusiastically received and was soon disseminated across the world where it became a classic reference for those involved in food sanitation and insect control. Dr. Monro served as consultant to both the Canada Department of Agriculture and F.A.O. and was constantly being called on for his opinions and advice on matters pertaining to insect control.

Dr. Monro was a long-time member of the Entomological Society of America; he served on the executive of the Entomological Society of Canada for several years and as president of both the Entomological Society of Ontario and the McIlwraith Field Naturalists' Club. Dr. Monro also made an outstanding contribution to the training of entomologists and plant quarantine specialists both in Canada and the United States. As an Honorary Lecturer in the Department of Zoology of the University of Western Ontario, he gave lectures to graduate students, and served on many examining committees for postgraduate degrees; he organized many training courses for plant quarantine inspectors and pest control operators in Canada, and on several occasions he lectured to similar groups in the United States for the U.S. Department of Agriculture. In 1967 he was invited to go to India to take part in the training of pest control specialists from the newly developing countries of South East Asia.

Many of Dr. Monro's friends and associates will well remember his famous limericks; of these he had a great repertoire, and he not only had the ability to remember and recite a host of them but he was also an expert at composing his own. Dr. Monro was widely read and had a vast store of knowledge that he made readily available to those about him. He had a pleasant and jovial disposition that made association with him a great pleasure. He will be sorely missed by all who knew him.

Dr. Monro is survived by his wife Alice, two sons, Alexander and Donald, a daughter Elizabeth (Smith), and three grandchildren.

E. J. Bond,
Research Institute, Canada Agriculture, London, Ontario

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of the

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I. REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

INSECTS OF THE SEASON 1971 RELATED TO FRUIT, VEGETABLES, FIELD CROPS AND ORNAMENTALS

H. W. Goble

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Abstract

A resume of the occurrence in Ontario in 1971 of several species of insects affecting fruit, vegetables, field crops and ornamental plants.

* * * * * *

Fruit

No serious infestations developed in 1970 that were not fairly well managed by control programs. The codling moth was conspicuous in some unsprayed orchards with no serious problems in those that were well managed. The apple maggot, *Rhagoletis pomonella* (Walsh), infestation was lower than in 1970 as shown by the Canada Department of Agriculture apple maggot inspection reports.

The tentiform leaf miner, *Lithocolletis blancardiella* Fab., was very plentiful in some apple orchards. These infestations were present in a few orchards in all apple-growing areas. The European red mite, *Panonychus ulmi* (Koch), continued to be one of the most important problems on tree fruit. The strawberry weevil, *Anthonomus signatus* Say, was a problem on strawberries in the Milton area. Although not widespread, Comstock mealybug, *Pseudococcus comstocki* (Kuwana), infestations occurred in several peach, pear and plum orchards in the Niagara Peninsula.

Vegetables

Cutworm damage was not as severe as in 1970. The red-backed cutworm, *Euxoa ochrogaster* (Guenée), was present in small numbers on onions, carrots and lettuce at Bradford Marsh. The black cutworm, *Agrotis ipsilon* (Hufnagel), was important in a few fields at Leamington but was not important on rutabagas. The cutworm situation on tobacco was normal.

The cabbage maggot, *Hylemya brassicae* (Bouché), was well controlled early in the season. The last generation of flies in late August and September was large and caused some damage on rutabagas. The cabbage looper, *Trichoplusia ni* Hübner, was present in very small numbers in all areas of Ontario. Species of thrips that contaminated asparagus during the cutting season in 1970, caused no

damage in 1971. Infestations of the European corn borer, *Ostrinia nubilalis* (Hübner) were relatively light in field corn but severe on some late sweet corn. Infestations in peppers were very severe with heavy losses to some growers. The infestation of the green peach aphid, *Myzus persicae* (Sulzer), in Essex and Kent counties was the heaviest in several years. Sap beetles, *Glischrochilus quadrisignatus* Say, continued to infest various fruits and vegetables. The problem is greatest on tomatoes and raspberries.

Field Crops

The alfalfa weevil, *Hypera postica* Gyllenhal, was distributed throughout all of Southern Ontario. Populations were heavy close to the lakes. The economic loss was light because the insects development was delayed by cool weather early in the season.

The cereal leaf beetle, *Oulema melanopus* (Linnaeus), was found across the province from Essex to Carlton counties. The numbers were small causing no economic loss. However, the spread in 1971 was considerable.

Except for a few fields, there was little loss on field corn from the northern corn rootworm, *Diabrotica longicornis* (Say). However, the adult beetles were very plentiful on many varieties of flowers in the fall especially on roses, dahlias and marigolds where some feeding damage occurred. Many flower infestations occurred at considerable distances from corn fields.

The Mexican bean beetle, *Epilachna varivestis* Mulsant, caused some damage to white beans in the Bayfield area within two miles of Lake Huron. There was no damage outside this area.

Ornamental Plants

Many species of insects and mites attacked various species of ornamental plants. Only a few of the more important will be listed.

The honey locust pod gall, *Dasyneura gleditschiae* O.S., was very severe on Moraine locust and its ornamental varieties in June. All new leaves were destroyed on some trees affecting growth and the aesthetic value. The birch leaf miner, *Fenusa pusilla* (Lepeletier) was important on birch plantings. The oak skeletonizer, *Buccalatrix ainsliella* Murtfeldt, was common on oak. Several species of sawflies, particularly the European pine sawfly, *Neodiprion sertifer* (Geoffroy), attacked pines in ornamental plantings. The mountain ash sawfly, *Pristiphora geniculata* (Hurtig), and the poplar sawfly, *Trichiocampus viminalis* (Fall.), were important. The hairy chinch bug, *Blissus leucopterus hirtus* Montandon, caused severe damage on some lawns in the Guelph and Windsor areas.

INSECTS AND OTHER ARTHROPODS OF IMPORTANCE DURING 1971 IN HOUSEHOLDS AND ON LIVESTOCK IN ONTARIO

W. C. Allan

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Abstract

A resume of the occurrence in Ontario in 1971 of certain species of insects and other arthropods in houses and on livestock.

* * * * * *

Household

Millipedes, *Narcus spp.,* were commonly found in and around houses during the spring and summer months. In many instances they appeared in very large numbers in driveways, cellarways and around swimming pools. Sowbugs, *Porcellio spp.,* were frequently found in basements and in storage areas. Fleas, *Ctenocephalides spp.,* were very common in houses and as was the case in previous years, severe infestations were closely related to the presence of dogs or cats in the home. Cluster flies, *Pollenia rudis* (Fabricius), while numerous in certain areas during the spring and early summer, were not as widespread as in 1970. Where heavy infestations occurred they were usually followed by larder beetles, *Dermestes lardarius L.*

In kitchens and pantries, saw-toothed grain beetles, *Oryzaephilus surinamensis* (Linnaeus), were reported many times during the year.

Livestock

Face flies, *Musca autumnalis* (DeGeer), while not as numerous as in past years, continue to be the most common pests of cattle and horses. Horn flies, *Haematobia irritans* (Linnaeus), were reported as being found on cattle over a wide area but in general populations were not large in any specific instance. Warble flies, *Hypoderma spp.,* were observed particularly in beef cattle, and in isolated areas some gadding was reported during the summer. Horse flies, *Hybomitra spp.,* were observed on cattle in some areas.

ECONOMICALLY IMPORTANT PLANT PARASITIC NEMATODES IN ONTARIO

Th. H. A. Olthof, C. F. Marks, J. W. Potter and J. L. Townshend

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Abstract

Eight genera of plant parasitic nematodes, including large numbers of *Pratylenchus,* were found in soil from Ontario peach and cherry orchards. *Longidorus elongatus* was detected in soils at Delhi and Harrow, Ontario. A nematode-complex

consisting of *Heterodera avenae* and *Pratylenchus* appears to be responsible for damage to oats and corn; species of *Paratylenchus, Helicotylenchus* and *Tylenchorhynchus* are also present. *Meloidogyne hapla* was responsible for serious damage to muck-grown vegetables. An unidentified root-knot nematode, *Meloidogyne,* sp. was associated with turf grasses. The reproductive potential of four nematode species was studied on four forage components. Field studies established relationships between population densities of *Pratylenchus penetrans* and *Meloidogyne hapla* and losses in several vegetable crops and tobacco. An experimental nematicide with bipolar systemic action was effective against the beet-cyst nematode, *Heterodera schachtii,* on cabbage.

* * * * * *

Introduction

Several destructive plant parasitic nematode genera occur in Ontario that have an important economic impact on crop production. These are the root-lesion nematode, *Pratylenchus* Filipjev; the root-knot nematode, *Meloidogyne* Goeldi; the cyst nematode, *Heterodera* Schmidt; the dagger nematode, *Xiphinema* Cobb; the bulb and stem nematode, *Ditylenchus dipsaci* (Kuhn) Filipjev, and the pin nematode, *Paratylenchus* Micoletzky.

Many observations during the past few years have shown that the root-lesion nematode, *Pratylenchus penetrans* (Cobb), is the most prevalent and most important nematode in peach and cherry orchards in Ontario. Pin nematodes, ring nematodes (*Criconemoides* Taylor) and *Xiphinema americanum* Cobb occur quite commonly, whereas stunt (*Tylenchorhynchus* Cobb) spiral (*Helicotylenchus* Steiner), sheath (*Hemicycliophora* de Man) and needle nematodes (*Longidorus* Micoletzky) are only occasionally found associated with fruit trees.

In 1971, *Longidorus elongatus* (de Man) Thorne & Swanger was found at Delhi and Harrow, Ontario, which suggests that this nematode may be more widespread than previously suspected. This nematode is destructive to strawberry in sandy soils and is an important vector of certain soil-borne viruses.

The oat-cyst nematode, *Heterodera avenae* Wollenweber, and the lesion nematode were detrimental to oats and corn in southwestern and eastern Ontario as in previous years (Olthof *et al.* 1969). Further sampling of corn and cereal-grain soils showed the presence of pin, spiral and stunt nematodes under corn and cereals, along with the oat-cyst and lesion nematode.

The northern root-knot nematode, *Meloidogyne hapla* Chitwood, was found to parasitize carrots, celery, onions, and potatoes grown in muckland soils near St. Jean, Quebec. The carrot crop was most severely affected; one grower lost his entire production in a 25 acre field. The spread of this pest appears to be accelerated by the practice of dumping plant root debris and wash water into drainage ditches where the nematode probably survives and multiplies on weeds.

The beet-cyst nematode, *Heterodera schachtii* Schmidt, which has been found associated with rhubarb in Ontario (Townshend & Olthof, 1967), was sought on rhubarb plants cultivar Timperley Early imported from England by A. Loughton, H.R.I.O., Vineland Station, Ontario. These plants were quarantined because of the presence of the nematode in England but tests revealed no infestation. These plants have now been cleared for propagation and eventual release to the Ontario winter forced rhubarb industry.

An unidentified root-knot nematode, *Meloidogyne* sp., was found associated with several cultivars of turf grasses in 1971. This discovery brings the number of root-knot nematode species surviving Ontario winters to two, the other one being *M. hapla.*

In a test on Guelph loam involving a mixed population of *Helicotylenchus digonicus* Perry, *Meloidogyne hapla, Paratylenchus projectus* Jenkins and *Pratylenchus minyus* Sher & Allen, on alfalfa cultivar Vernal, red clover cultivar Canadian Double-cut, trefoil cultivar Viking and timothy cultivar Climax, the only species that reached large numbers on alfalfa was *H. digonicus,* whereas *P. projectus* was the only one that increased considerably on trefoil and timothy. Both *M. hapla* and *P. minyus* maintained themselves on the three leguminous forages; however, only *P. minyus* did so on the grass forage timothy.

Micro-plots (Olthof & Potter, 1971) were used to expose seven summer-maturing vegetables to five population densities of the root-lesion nematode, *Pratylenchus penetrans,* in the field. Losses in marketable yields at the two highest densities (2,700 and 8,100 per pound of soil) were, respectively: cabbage, 26% and 38%; cauliflower, 15% and 58%; lettuce 39% and 46%; sweet corn, 32% and 49%; potatoes, 32% and 43%; onions, 41% and 71%, and tomatoes, 14% and 45%. In the fall, similar nematode densities of the northern root-knot nematode, *Meloidogyne hapla,* were tested on lettuce, beets, and spinach and the losses caused at the two highest densities were, respectively, 68% and 81%; 13% and 21%, and 9% and 13%.

The relationship between population densities of *Pratylenchus penetrans* and crop losses in flue-cured tobacco was studied in large micro-plots at Delhi, Ontario. At densities of 900, 2700 or 8100 nematodes per pound of soil, crop losses amounted to $87, $163 and $410 per acre, respectively.

The beet-cyst nematode, *Heterodera schachtii,* is known to attack cabbage and other crops of the genus *Brassica* in Ontario (Townshend & Olthof, 1967). Tests involving an experimental nematicide with bipolar systemic action have shown the compound to be effective against the beet-cyst nematode when applied to foliage as a post-plant spray combined with soil treatment. The results indicate that a satisfactory post-plant treatment may become an alternative to the present recommendation of pre-plant soil fumigation.

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NOTEWORTHY FOREST INSECTS IN ONTARIO IN 1971

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Abstract

A resumé is given of important and noteworthy forest insect conditions in 1971. The species dealt with are segregated as indigenous or introduced and further divided under coniferous or broad-leaved trees.

* * * * * *

Indigenous Insects

Coniferous Trees

Once again the spruce budworm, *Choristoneura fumiferana* Clemens, has dominated the forest insect scene in eastern Canada. In Ontario alone, white spruce and balsam fir in 13 million acres of forest, almost twice the area involved in 1970, suffered moderate to severe defoliation by this pest. Infestations were present in the southeastern, northeastern, and northwestern sections of the Province. The southeastern infestation, involving some 4.5 million acres of the Ottawa Valley from Ottawa to Deux Rivières and the eastern part of Algonquin Provincial Park, lies south of much larger infestations in Quebec. Forecasts based on numbers of hatched egg clusters taken in and around the affected area call for a continuation of heavy feeding in 1972 and a further southward extension of infestations. Massive moth flights were observed in the infested area and also as far afield as Toronto where the multitude of moths attracted to lights caused considerable public comment. Since female moths were in these flights, ornamental spruces in invaded cities may be harbouring high larval populations and widespread damage could occur in 1972.

In northeastern Ontario, there were a number of discrete infestations involving over 8.5 million acres. The largest stretched northeastward from Lake Superior, south of Michipicoten, in a band 60 miles wide by 160 miles long. Other large infestations occurred 30 miles north and northwest of Sudbury and beyond. The general forecast for this area for 1972 is continued heavy defoliation and a major, broad southward extension of the infestation.

Much smaller infestations totalling approximately 130,000 acres were present in northwestern Ontario near the International Border from the Height of Land west to Rainy Lake, and forecasts are for a continuation of moderate to severe defoliation with no increase in the affected area.

Small chemical control operations using aerial application of fenitrothion were carried out in each section. These involved just over 80,000 acres and were part of an overall control strategy directed toward protection of high-value research plots, foliage protection in parks, and reduction of populations in stands posing a threat to adjacent higher value stands.

Infestations of the jack pine budworm, *Choristoneura pinus pinus* Freeman, persisted southwest of Lake Nipissing, and moved slightly eastward in the northern part of the Georgian Bay Provincial Forest. Only remnants of the past outbreak

remain in the eastern part of Algonquin Provincial Park. However, in northwestern Ontario new infestations, totalling 75 square miles and located 50 miles southeast of Dryden, pose a threat to extensive stands of jack pine. Egg cluster counts there indicate a continuation and expansion of the infestation in 1972.

The balsam fir sawfly, *Neodiprion abietis* complex, continued to defoliate balsam fir heavily along the Ottawa Valley between Pembroke and Ottawa and, in conjunction with the spruce budworm, it is probably responsible for some heavy tree mortality observed in the Bonnechere Valley. Cedar leaf miners, *Argyresthia thuiella* Packard, *A. aureoargentella* Brower, *A. canadensis* Freeman, and *Pulicalvaria thujaella* Kearfott, prevalent in southern Ontario from Georgian Bay to Ottawa, caused severe injury especially in southeastern counties where, following 4 years of attack, branch and tree mortality are expected to occur. Heavy needle drop of Scots pine, the result of feeding by a cecidomyid larva, continues to plague Christmas tree growers east of Smiths Falls. Populations of most native diprionid sawflies were at their lowest levels in at least 10 years.

Broad-leaved Trees

In 1970, trembling aspen was defoliated over a considerable area in northern Ontario by the large aspen tortrix, *Choristoneura conflictana* Walker, and a leaf tier, *Enargia decolor* Walker, but it was sometimes impossible to delineate the area affected by each. Because of a substantial decline in the affected area in 1971, it was possible to determine more completely the insect responsible at each location. Small moderate-to-severe infestations of the large aspen tortrix ranging in size from a few hundred acres to 500 square miles were liberally scattered across the whole of northern Ontario (Sippell *et al.,* 1972). Some of these infestations have persisted for 4 years near the Lakehead and new infestations are occurring further west. *E. decolor* infestations were confined mainly to an area near the Quebec border from Mattawa to Lake Abitibi. A third aspen defoliator, the forest tent caterpillar, *Malacosoma disstria* Hübner, which has infested up to 600 square miles of aspen northwest of Fort Frances ever since 1965, is showing signs of an upsurge with small, new, light infestations reported in northwestern and northern Ontario and more frequent collections of larvae, pupae, and adults throughout the Province.

The massive infestation of the birch skeletonizer, *Bucculatrix canadensisella* Chambers, in northwestern Ontario in 1970 south of the 50th parallel persisted, but the assessment of the degree of damage caused by the skeletonizer was obscured by early leaf fall in that area brought about by other causes. Two other major heavy infestations of this skeletonizer included (a) the triangular area bounded on the north by Highway 11 from Lake Nipigon to Kapuskasing, thence by a line southwest to Wawa and northwest along the shore of Lake Superior, and (b) the area bounded by a line joining Espanola, Sudbury, the south end of Lake Temiskaming, along the Ottawa River to Deep River, southwest to Huntsville and northwest to Espanola. Smaller infestations were reported along the North Channel and near Canadian Forces Base, Borden and near Uxbridge in southern Ontario.

Three species of the genus *Anisota* caused damage. The green-striped maple-worm, *A. rubicunda* Fabricius, caused moderate defoliation of red maple on Cockburn Island and south of Highway 17 from Sudbury to Deep River. The pink-striped oakworm, *A. virginiensis* (Drury), defoliated red oak on Bien Venu Island in Georgian Bay and the orange-striped oakworm, *A. finlaysoni* Riotte, defoliated all species of oak in the Kingston/Belleville area.

Black cherry in two areas located northeast of both Gravenhurst and Bowmanville was severely defoliated by the looper, *Hydria prunivorata* Ferguson. This is the second year that damage has been heavy in these general areas.

Introduced Insects

Coniferous Trees

The range of the European pine sawfly, *Neodiprion sertifer* (Geoffroy), remained essentially unchanged from 1970, but in the outlying pockets of infestation in Sault Ste. Marie and Ottawa the intensity of attack increased. The sertifer virus, introduced into outlying infestations in plantations on Manitoulin Island, was recovered from the low populations that exist there. That the introduced pine sawfly, *Diprion similis* (Hartig), is established in Sault Ste. Marie was confirmed by two collections from a Scotch pine planting there; and in the vicinity of Fort Frances, light population levels up to 10 miles east and north of the known range in 1970 indicate that it is spreading there. The nursery pine sawfly, *Diprion frutetorum* Fabricius, has extended its range northward to the vicinity of Sundridge. The larch casebearer, *Coleophora laricella* (Hübner), has now been found near Sioux Narrows, an appreciable extension of its northern limit in northwestern Ontario.

Broad-leaved Trees

The smaller European elm bark beetle is apparently well established in Sault Ste. Marie since it was recovered at two additional sample points well removed from the first collection point; however, its ability to survive there apparently depends on snow cover since larvae in all unprotected brood material died. A collection from Fenelon Falls indicated a minor northward extension in range in southern Ontario. The known distribution of two birch leaf miners increased when *Fenusa pusilla* Lepeletier and *Messa nana* Klug were collected in and around Quetico Provincial Park and near Perth, respectively. The European snout weevil, *Phyllobius oblongus* Linnaeus, is not regularly collected, but it has occasionally occurred in large numbers, as it did this year, when severe defoliation of mostly broad-leaved trees was recorded on a golf course on Manitoulin Island and at two locations in and around Sault Ste. Marie. The chemical control measures carried out against the gyspy moth, *Porthetria dispar* Linnaeus, by the Plant Protection Division, Canada Department of Agriculture, have apparently held this pest within its containment area of approximately 12,000 acres near Kingston. However, a new invasion of the Province has occurred in Prescott County where 20,000 acres have been infested.

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II. SUBMITTED PAPERS

AGGREGATION OF ALATE CARPENTER ANTS IN ONTARIO

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Abstract

Aggregations of alate and dealate female and male carpenter ants (*Camponotus herculeanus* (L.)) were observed in 2 successive years on the ground in a clearing on the shores of Black Sturgeon Lake, northwestern Ontario. The presence of dealate females indicates that mating had already taken place, suggesting that the ants had formed aerial swarms elsewhere and had been attracted to the lake shore or deposited there by convectional air movement.

* * * * * *

The alates of many species of ants form conspicuous swarms during their mating flights, the term "swarm" implying an aggregation of flying ants visible to the human observer. Generally, mating flights of carpenter ants of the genus *Camponotus* Mayr are inconspicuous, the alates leaving the colony singly and flying up until out of sight (Eidmann 1929; Marikovsky 1956; Sanders 1964). It is assumed that copulation takes place on the wing, in common with most ants, although Goetsch and Kathner (1937) and Marikovsky (1956) have recorded copulation on the ground. Reports of the relatively conspicuous alate and dealate females on the ground after mating flights are common; but there are no reports of alate carpenter ants forming conspicuous aerial swarms, although the synchronization of flights from different colonies may produce a sufficient density of flying ants to attract large numbers of birds (Veitinghoff-Riesch 1928). The occurrence of congregations of alate *C. herculeanus* (L.) in Ontario in 1967 and 1968 is therefore worthy of comment, because it suggests that swarming must have taken place.

In 1967 a concentration of female and male *C. herculeanus* was discovered at the edge of Black Sturgeon Lake, northwestern Ontario. The ants were confined to a small bay which faces northeast, at the southern end of a partially cleared area occupied by a Canadian Forestry Service field station. The large congregation of ants was first noticed at 0930 EST, 30 May, although some dealate females had been seen near the area the previous evening. The following day, 31 May, a count of the ants per linear foot of shore line, made at 10-ft intervals, gave an estimate for the total number of ants as 15,000. The ratio of males to females was 7:1; both partially dealate and dealate females were found. By the afternoon of 1 June, fewer than 100 ants were visible, although numerous dealate females were concealed in and under logs and driftwood. At no time were any worker ants seen.

During the evening of 31 May, the surface of the bay and the open lake was dotted with alate carpenter ants as far as the eye could see. An area approximately 300 x 100 yd was traversed by canoe and the density of ants was estimated at one per sq yd. A few of the male ants on the water were seen taking off again; but most of them, and all of the females, appeared unable to do so.

Apart from the alates on the water, the ants were confined to a 100-ft stretch of shore line; a search for several hundred yards in both directions along the shore, which included another bay, and in the surrounding forest, failed to reveal any other congregations. The ants were found only at the edge of the water, many of them on rocks projecting out of the water or on floating or beached logs. Most of the shore line is rocky and littered with driftwood and logs up to 18 in. in diameter, and there was apparently nothing distinctive about the shore line where the ants were located except its sheltered location in the bay and its proximity to the partially cleared area on the shore.

The weather during this period was calm and mild. On 25 May the ambient air temperature reached 20°C, the first time it had exceeded 16°C since 16 May. Maxima of 16°C or above were recorded throughout the observation period, with 21°C on 28 May, 24° on 31 May, and 29° on 1 June. Skies were clear throughout the period. Air movement was from the east-northeast throughout and never exceeded 7 mph.

Locomotion and flight of the ants was governed by wind, being most intense during complete calm, when counts of up to five alates per minute, both male and female, took wing per linear foot of shore line. Male flight activity was less restricted by the wind than that of the females. As the wind speed increased, the ants congregated in inactive groups of 10 to 100 in areas protected from sun and wind. Each group contained an apparently random collection of alate and dealate females and males. Contacts between the ants were frequent, often resulting in the exchange of food. No copulation was seen, although male ants were seen to move behind or to the side of alate females and to antennate them rapidly. Such encounters never proceeded further than this and usually ended with the female walking away.

Many females were observed breaking off their wings, a characteristic of all alate female ants after mating. In most instances, the gaster was twisted to one side and at the same time the wings on the opposite side were brought forward and pressed down against the substrate, either by a downward flexion of the wings or by a rotation of the thorax. Sometimes the wings were brought forward through 90° but usually the angle was less. Often a middle or hind leg was brought down over the wing in a hooking motion. More rarely ants twisted the head back towards the wing with the mandible open as if attempting to bite the wing, but in no instance did an ant succeed in reaching the wing with the jaws. This behaviour often resulted in the wings being rubbed against projections. However, such encounters were apparently accidental and there was no indication of deliberate attempts to use projections to aid in wing removal. Breakage, when it did occur, was sudden and complete. On at least one occasion a drop of liquid was seen at the point of breakage, but this could have come from either the wing or the thorax. Many females were seen with only one, two or three wings present, and these were often held at unusual angles.

During the evening of 1 June, when the congregation had virtually disappeared, numerous alate females, but no males, were seen flying horizontally among

the open-grown trees in the field station, at a height of between 5 and 20 ft. Individual females were observed flying back and forth over distances of several hundred feet, showing considerable maneuverability among the trees. When they encountered and alighted on an obstacle, they immediately attempted to take wing again. This activity was in marked contrast to the maiden flights, where the females and males fly upwards until out of sight.

The following year, 1968, there was further evidence of alate ants congregating in the vicinity of the field station. The first alate female *C. herculeanus* was noticed on the ground in the field station at noon, 31 May. Numbers peaked in the late afternoon and decreased in the evening. The following afternoon a few dealate females were seen. At 1600 on 31 May counts of the number of ants in 35 random 1-sq-yd quadrats gave an average of 2 ants per sq. yd. None were noticed along a bush road approximately ½ mi away. No males were seen, and there was no massing of the ants, as there had been the previous year. Instead, most were walking over the ground, facing the wind. Although most of the ants were dealate, alates were also present, taking flight or landing on the ground or on obstructions such as buildings and trees.

The weather was similar to that of the previous year; the temperature reached 18.5°C on 30 May, and 22°C on 31 May, with clear skies, low humidity and light easterly winds, following 10 days of cool, wet weather during which the temperatures exceeded 16°C only once.

The number of alate ants in the vicinity of the field station in both 1967 and 1968 was too great for them to have been spread over large areas in such density. Under optimal conditions there are probably no more than two mature colonies producing alates per acre, and 2,000 is the maximum number of alate females that can be expected from one colony (Sanders 1970), yielding a total of 4,000 alate females per acre, less than one per sq yd. In 1967, the 15,000 ants included nearly 2,000 females, and the density of ants on the lake was estimated at 1 per sq yd although the ratio of males to females was not recorded. A search of the adjacent forest revealed no colonies, and the absence of workers suggests that the ants arrived by air. In 1968 the maximum density of alate females was estimated at 2 per sq yd in the grounds of the field station, and away from the station numbers decreased rapidly. It must, therefore, be concluded that the ants had concentrated in the vicinity of the field station. If mating did take place in the air, then probably the observed congregation of dealate females represented single swarms that formed elsewhere and arrived intact in the area of the field station. No aerial swarming was noticed, nor has it been recorded for carpenter ants. However, the ants may form loose swarms high in the air where they are inconspicuous from the ground. A tendency to aggregate would be facilitated by the synchronous flighting of carpenter ants over large areas regulated by climatic conditions and by an odour released by the males which activates the females (Hölldobler and Maschwitz 1965).

Since the congregations occurred in the same place in two successive years, some characteristic of the field station itself or its location probably attracted the ants. In many species of ants, the alates gather above prominent objects, but in the boreal forest there are few such objects and lakes are probably the most conspicuous feature of the landscape. Possibly alate carpenter ants are attracted to these and form swarms over them. Alternatively, air circulation in the spring, rising over the warm land and descending over the cool water, would passively transport the ants and deposit them in or near lakes.

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PSOCOPTERA COLLECTED NEAR BELLEVILE, ONTARIO

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Abstract

Records are given of 24 species of Psocoptera captured in and around Belleville, Ontario in 1969 and 1970. One species, *Trichadenotecnum majus* (Kolbe) is recorded as new to North America, and the brachypterous form of *Matsumuraiella contermina* (Walsh) described in detail for the first time.

* * * * * *

Introduction

The Psocoptera are amongst the least-known groups of insects in Canada, and there are few or no Canadian records of species known to be widely distributed in the United States. Since the account of North American psocids by Chapman (1930), in which records for four species found in Canada were summarised, few authors have recorded Canadian species, other than the few genera containing stored products pests *(Liposcelis, Lepinotus).* Later records are given casually in papers primarily devoted to descriptions of United States species (Sommerman, 1946; Mockford 1965, for examples) or to more detailed ecological surveys (Matthewman & Pielou, 1971; Powell, 1971).

This paper is a list of Psocoptera collected in and around Belleville, Ontario (44°10'N., 77°23'W.) during 1969-1970; about 500 specimens were collected by TRN from July 1969 to May 1970, and a smaller more systematic collection was made by CCL during 1970, as part of a project on the biology of euphorine Braconidae parasitising Psocoptera.

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Twenty-four species were collected, including one new to North America. The list is by no means comprehensive; it is likely that many further species occur in Ontario and, as the distribution of Psocoptera is so inadequately known, the value of any zoogeographic discussion is limited. Most species collected are arboreal. Belleville is situated in the Huron-Ontario Section of the Great Lakes - St. Lawrence region of the Tolerant Hardwoods Division of forest types (discussed by James *et al.*, (1970). Most of the tree species from which samples were taken occur naturally in this area. James *et al.* (1970) also pointed out that Belleville forms part of an extension of the Carolinian zoogeographical region associated with beech-maple forests, and some species of psocids found are therefore probable southern elements. Only extensive further collecting in other parts of Canada can determine the affinities of the species so far found around Belleville. Many of them appear to be very widely distributed in the United States and some (*Lachesilla pedicularia, L. nubilis, Caecilius aurantiacus*) have been found in widely separated regions of Canada.

List of Species

Lepidopsocidae

Echmepteryx hageni (Packard).

Material examined : 4 VIII. 1969, *Salix,* 2♀♀; 12. IX. 1969, on fenceposts, 1♀; 3. VII. 1970, *Malus,* 2♀♀ and 2 small nymphs; 15. VII. 1970, *Crataegus,* 1 last instar nymph.

This species is widely distributed in eastern North America, but rarely found in large numbers. It is apparently univoltine, and males are found in much smaller numbers than females.

Trogiidae

Cerobasis guestfalica (Kolbe).

Material examined : 18. X. 1969, *Pinus,* 6♀♀.

A widely distributed species found in many parts of the world.

Lepinotus reticulatus (Enderlein).

Material examined : 31. V. 1970, dead grass, 1♀ and several probable nymphs.

A cosmopolitan species often associated with stored products.

Liposcelidae

Embidopsocus needhami (Enderlein).

Material examined : 28. IX. 1969, *Pinus,* 1 apterous ♀, 18. X. 1969, *Pinus,* 1 apterous ♀.

Although this may be a widely-distributed subcortical species in North America (Mockford 1963), this is apparently the first record for Canada.

Epipsocidae

Epipsocus (Bertkauia) lepicidinarius (Chapman)

Material examined : Foxboro, 4. VII. 1970, *Solidago* litter, 17♀♀, 1 nymph.

This series shows a considerable variation in size and colouration, some specimens approaching *E. (B.) crosbyana* (Chapman). A univoltine litter-frequenting species, as is the related European *E. (B.) lucifugus* (Rambur) (New, 1969).

Caeciliidae

Caecilius aurantiacus (Hagen)

Material examined : 12. X. 1969, *Quercus,* 1♂, 3♀♀, Foxboro, 14. VI. 1970, *Prunus* 4♀♀.

A common and widely distributed North American species found predominantly on broadleaved trees (Mockford, 1965).

C. pinicola (Banks)

Material examined : 28. IX. 1969 —25. X. 1969, *Pinus,* 5♂♂, 11♀♀.

This species is again widely distributed in eastern North America, and is apparently limited to coniferous foliage (Mockford, 1965).

C. posticus Banks

Material examined : 20. VI. 1970 - 8. VII. 1970, Foxboro, *Solidago* litter, 2♂♂, 3 brachypterous ♀♀, 1 nymph.

Predominantly a litter-frequenting species.

Matsumuraiella contermina (Walsh)

Psocus conterminus Walsh, 1863, *Proc. ent. Soc. Philad.* 2 : 185.

Teliapsocus conterminus (Walsh). Chapman, 1930, *J.N.Y. ent. Soc.* 38 : 334.

Matsumuraiella contermina (Walsh). Smithers, 1970, *Proc. R. ent. Soc. Lond. (B)* 39 : 81.

Material examined : 18. VI. 1970, Foxboro, *Solidago* litter, 1 brachypterous ♀.

Smithers (1970) transferred the species then known as *Teliapsocus conterminus* (Walsh) to *Matsumuraiella* on the basis of examination of macropterous specimens. The brachypterous form appears to be rare and has not been described in detail, although Chapman (1930) gave brief details of specimens collected in New York. This form is described below : this individual differs in several important details from the macropterous specimens described by Smithers (1970). In particular, it has setae on the gonapophyses (Fig. 4), and the subgenital plate more resembles Chapman's (1930) figure.

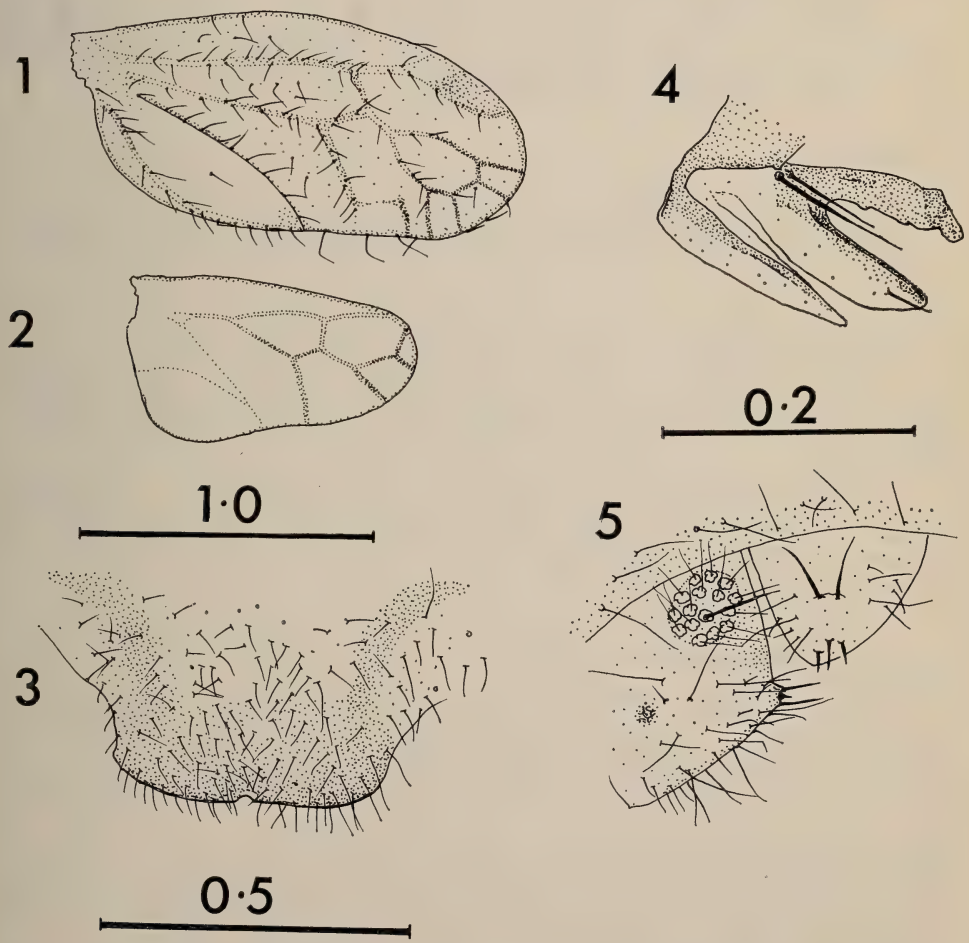
Brachypterous female. Colouration. Mainly as macropterous form but forewings slightly yellowed and marked with yellowish brown as in Figure 1.

Morphology. Ocelli reduced. Forewing (Fig. 1) with apical region strongly reduced; veins with long setae, and few similar setae on membrane of basal cells. Hindwing (Fig. 2) bare, tapered; anal lobe broad. Subgenital plate (Fig. 3) broad, with slight median indentation. Gonapophyses (Fig. 4) with ventral valve tapered; dorsal valve broad with short seta near apex; external valve reduced, heavily sclerotised and with two long setae near base. Epiproct (Fig. 5) tapered, with row of three short conical setae near apex, two strong median setae and small

lateral setae. Paraproct (Fig. 5); inner margin with small hyaline cone flanked by stronger setae; a field of 16 trichobothria. Basal hind tarsal segment with 14 ctenidia, some weakly developed.

Dimensions (mm). Body length 3.50, forewing length 1.462, hindwing length 0.952, first flagellar segment (f1) 0.544, second flagellar segment length (f2) 0.561, f1/f2 0.970; hind femur length 0.988, hind tibia length 1.530, basal hind tarsal segment length (t1) 0.328, second hind tarsal segment length (t2) 0.200, t1/t2 1.64.

TRN has examined specimens of *Matsumuraiella radiopicta* Enderlein collected in Japan, and this species was further discussed by Tsutsumi (1961). Smithers' (1970) synonomy of *Teliapsocus* with *Matsumuraiella* appears justified on many structural characters, but variation in the setal complement of the gonapophyses of *M. contermina* may indicate at least a subgeneric difference when longer series have been examined.



FIGURES I-V. *Matsumuraiella contermina* (Walsh), brachypterous female. 1. Forewing. 2. Hindwing. 3. Subgenital plate. 4. Gonapophyses. 5. Epiproct and paraproct. (Scales in mm, 1 and 2 to same scale, 3 and 5 to same scale).

Polypsocidae

Polypsocus corruptus (Hagen)

Material examined : 20. VI. 1970, swept from *Spirea,* 1♀.

Lachesillidae

Lachesilla nubilis (Aaron)

Material examined : 4. VIII. 1969, *Salix,* dead in spider web, 1♂; 4. VII. 1970, *Solidago* litter, 1♀.

Among the records given for this common species by Sommerman (1946) is one from Saskatchewan.

L. pedicularia (L.)

Material examined : 22. X. 1969, dead grass, 16♂♂, 29 macropterous ♀♀, 11 brachypterous ♀♀, many nymphs; 31. V. 1970, dead grass, 2♀♀, many nymphs.

A cosmopolitan, often abundant species.

Peripsocidae

Peripsocus madascens (Walsh)

Material examined : 30. VI. 1970 - 17. VII. 1970, *Acer, Crataegus, Malus,* 6♀♀.

P. madidus (Hagen)

Material examined : 4. VIII. 1969 - 7. IX. 1969, *Salix,* 10 ♂♂, 3 macropterous ♀♀, 31 brachypterous ♀♀, 49 nymphs; 14. VI. 1970 - 15. VII. 1970, *Crataegus, Malus, Populus, Prunus, Psuga,* 1♂, 21 macropterous ♀♀, 18 brachypterous ♀♀.

Females of this species were clearly more numerous than males, and brachypterous forms are frequent. Found on the bark of many broadleaved trees, and apparently bivoltine near Belleville.

P. quadrifasciatus (Harris)

Material examined : 28. IX. 1969 - 25. X. 1969, *Pinus,* 113 ♀♀, 14. VI. 1970, Foxboro, *Prunus,* 1♂, 3♀♀.

Eertmoed (1966) discussed some aspects of the ecology of this species in North America. It is widely distributed, and some populations are composed entirely of females. *P. quadrifasciatus* is extremely similar to the European *P. subfasciatus* (Rambur).

Pseudocaeciliidae

Anomopsocus amabilis (Walsh)

Material examined : 14. VI. 1970, *Ostrya,* 1♂

Life history discussed by Sommerman (1944).

Mesopsocidae

Mesopsocus unipunctatus (Mueller)

Material examined : 15. V. 1970 - 12. VII. 1970, *Acer, Malus, Prunus Sambucus, Ostrya, Larix,* 13 ♂♂, 19 ♀♀, 8 nymphs.

M. unipunctus appears to be a univoltine early summer species in Canada, as it is in Europe, and is found on many kinds of trees.

Psocidae

Blaste inornata (Aaron)

Material examined : 7. IX. 1969 - 12. IX. 1969, on wooden fenceposts, 5 ♂♂, 17 ♀♀, 19. VI. 1970-17. VII. 1970, *Ulmus, Malus Crataegus, Tilia,* 3 ♂♂, 19♀♀; 7. VII. 1970, Foxboro, on fencepost, 8♀♀; 8. VII. 1970, Kaladar, *Salix, Alnus,* 2♀♀.

Metylophorus purus (Walsh)

Material examined: 7. IX. 1969, on wooden fenceposts, 5♂♂, 12♀♀, 9. VII. 1970, *Crataegus,* 4♀♀.

Hyalopsocus striatus (Walker)

Material examined : 7. IX. 1969, on wooden fenceposts, 1♂, 9♀♀; 21. VI. 1970-17. VII. 1970, *Acer, Crataegus, Malus, Tilia, Psuga,* 6♂♂, 11♀♀.

Psocidus pollutus (Walsh)

Material examined : 7. VII. 1970-14. VIII. 1970, *Crataegus, Larix,* 5 ♀♀.

Trichadenotecnum alexanderae Sommerman

Material examined : 7. IX. 1969, on wooden fencepost, 1♀; 28. IX. 1969-18. X. 1969, *Pinus* 3♂♂, 2♀♀; 12. VII. 1970, *Acer,* 2♀♀, 8. VII. 1970, Kaladar, *Alnus* 2♀♀.

T. majus (Kolbe)

Psocus sexpunctatus var. *major* Kolbe, 1880, *Jber. westf. Prov Ver. Wiss. Kunst. 8* : 109.

Psocus major (Kolbe) - Loens, 1890, *Stettin. ent. Ztg.* 51 : 6.

Trichadenotecnum majus (Kolbe). Enderlein. 1909, *Boll. Lab. zool. Portici 3* : 330.

Material examined : 22. VI. 1970-17. VII. 1970, *Betula, Ulmus, Sambucus, Malus, Crataegus, Larix,* 19♀♀.

This species is widely distributed, although not common, in Europe but has not hitherto been recorded from North America. The Belleville specimens have been carefully compared with specimens collected in Britain and, although only females were found in the Canadian series, there is no doubt that the same species is represented. The subgenital plate (figured by Badonnel, 1943) is especially distinctive and unlike that of any other known *Trichadenotecnum* species. The Canadian specimens are slightly smaller than most British material seen, but the differences are not sufficient to indicate other than population differences.

Sommerman (1948) showed that there are several very similar Nearctic *Trichadenotecnum* species and, in his discussion of psocid species common to Europe and North America, Gurney (1949) discounted Aaron's (1883) Philadelphia record of the European *T. sexpunctatum* on these grounds. *T. majus* and *T. sexpunctatum* are superficially rather similar and, as *T. majus* appears to be well established in southern Ontario, it is remotely possible that *T. sexpunctatum* may also be present. In Europe, the biology of the two species is very similar and their early stages are not separable with any certainty.

Loensia moeste (Hagen).

Material examined : 7. IX. 1969, *Salix* bark, 3♀♀.

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THE ADELGIDAE (HOMOPTERA) ON FOREST TREES IN ONTARIO WITH A KEY TO GALLS ON SPRUCE

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Abstract

The Adelgidae on forest trees in Ontario are listed with information on distribution, host plant, feeding site, and abundance. Descriptive notes and references and a key to spruce gall adelgids are included.

* * * * * *

Introduction

This paper on the Adelgidae (Phylloxeridae, Chermidae) of Ontario forest trees is a sequel to an earlier compilation on a closely related group, the Aphididae (Lindquist and Miller 1970). In Ontario, adelgids occur on only one genus of deciduous trees, *Carya* (hickory), and on three genera of conifers, *Larix* (larch), *Picea* (spruce) and *Pinus* (pine). Fourteen species of adelgids are currently known, most of which alternate between spruce and another conifer. Quantitative information was drawn from the records of the Forest Insect and Disease Survey, Canadian Forestry Service, dating from 1950 to 1968.

The adelgids are listed alphabetically by host tree genus. Distribution is indicated by reference to numbered forest districts which can be located on the map shown in Fig. 1. The number in brackets following the host species indicates the total number of Survey collections.

A key to adelgid galls on spruce, commonly referred to as the spruce gall "aphids", follows the alphabetical listing. This is a revised and expanded version of earlier keys by Patch (1909) and Brown (1941).

Adelgids on Forest Trees

Carya (hickory)

Phylloxera caryaecaulis Fitch Districts: 2 and 6. Host species: *C. ovata* (Mill.) K. Koch (2), *C. cordiformis* (Wang.) K. Koch (1), *Carya* sp. (2). Collected: June and early July. Comments: forms a globose, conical, spiny or smooth petiole or twig gall ¼ to 1 inch in diameter (Felt 1940).

FIGURE I. Forest districts of Ontario.

P. caryaeglobuli Walsh Districts: 1 and 6. Host species: *C. ovata* (1), *Carya* sp. (1). Collected: June. Comments: forms a subglobose leaf gall ⅓ to ½ inch in diameter (Felt 1940).

Larix (larch)

Adelges lariciatus Patch Districts: 4 to 8. Host species: *L. laricina* (Du Roi) K. Koch (6), *L. decidua* Mill. (3). Collected: mid-May to late August. Comments: associated with buds or cones, galls are produced on the primary host *Picea glauca* (Moench) Voss (Cumming 1968).

A. strobilobius Kalt. Districts: 1, 2, 4, 7, and 9. Host species: *L. decidua* (5), *L. laricina* (2). Collected: early June to late July. Comments: feeds on needles or in cones (Speyer 1923; Kettela and Brown 1968), galls are produced on the primary host, *P. mariana* (Mill.) B.S.P.

Picea (spruce)

Adelges abietis Linn. Districts: 1 to 10, 14, and 19. Host species: *P. glauca* (363), *P. abies* (L.) (45), *P. mariana* (23), *P. rubens* Sarg. (1). Collected: early June to late August. Comments: yellow pulverulent nymphs in pineapple galls that are not terminal on shoots, gall-needles about ⅓ normal length and not swollen beyond gall; no alternate host is known (Patch 1909).

A. cooleyi Gill. Districts: 3 and 4. Host species: *P. pungens* Engelm. (2). Collected: July. Comments: reddish-brown pulverulent nymphs in terminal elongate galls with gall-needles about normal length; *Pseudotsuga menziesii* (Mirb.) Franco is the alternate host (Cumming 1959).

A. lariciatus Patch Districts: 1 to 22. Host species: *Picea glauca* (222), *P. mariana* (48), *P. abies* (3). Collected: early June to early August. Comments: reddish flocculent nymphs in pineapple galls that are not terminal on shoots, gall-needles less than ⅓ normal length; *Larix* spp. is the alternate host (Cumming 1968).

A. strobilobius Kalt. Districts: 1 to 22. Host species: *P. mariana* (190), *P. glauca* (8). Collected: mid-June to mid-August. Comments: dark red flocculent nymphs in small terminal galls that are pale green or pink, gall-needles short; *Larix* spp. is the alternate host (Patch 1909; Annand 1928).

Pineus sp. *coloradensis* grp. District: 20. Host species: *Picea glauca* (1). Collected: early July. Comments: flocculent nymphs on new and old foliage, no galls are formed.

Pineus floccus (Patch) Districts: 1 to 22. Host species: *Picea mariana* (140+), *P. rubens* (4), *P. glauca* (4+). Collected: mid-June to mid-August. Comments: reddish pulverulent nymphs in terminal elongate galls with gall needles about normal length; the alternate host is *Pinus strobus* (Patch 1909; Annand 1928).

Pineus pinifoliae Fitch Districts: 7, 9 to 22. Host species: *Picea mariana* (33), *P. glauca* (29). Collected: early June to late July. Comments: reddish-brown, sparsely flocculent nymphs, one per chamber, in terminal cone-like galls with needles modified to thin scales (Patch 1909; Underwood 1955). The alternate host is *Pinus strobus.*

Pineus similis Gill. Districts: 1 to 22. Host species: *Picea glauca* (220), *P. mariana* (37), *P. abies* (2), *P. rubens* (1). Collected: early June to early August. Comments: reddish brown nymphs or winged or wingless adults in galls that are compact when young but with no lateral joining of tissue between swollen bases of needles. Mature galls have a ragged appearance, often with flocculent secretions from wingless females; there is no alternate host (Cumming 1962).

Pinus (pine)

Pineus coloradensis Gill. Districts: 4, 5, 8, 10, and 14. Host species: *Pinus strobus* L. (5), *P. divaricata* (Ait.) Dumont (3), *P. resinosa* Ait. (3). Collected: May to mid-October. Comments: flocculent females near base of needles on previous year's twigs in spring, flocculent nymphs on new shoots in June, rusty brown nymphs on needles often with associated green to black fungus in the fall (Annand 1928; Doane 1961).

Pineus floccus Patch District: 14. Host species: *Pinus strobus* (2). Collected: mid-July. Comments: females on needles of new or old growth with a large amount of flocculent wax; the alternate host is *Picea* spp. (Patch 1909; Annand 1928). Nymphal feeding site is unknown.

Pineus pini (L.) Districts: 7 and 14. Host species: *Pinus resinosa* (10), *P. divaricata* (3). Collected: mid-May to early September. Comments: flocculent female and eggs at the top of needle sheath in early spring, nymphs on new shoots, and flocculent females and eggs at the base of cones in the fall. (The use of the species name *pini* is provisional pending further study.)

Pineus pinifoliae Fitch Districts: 7, 9, 10, 14, 19, 21, and 22. Host species: *Pinus strobus* (11). Colllected: June to late August. Comments: females on previous year's needles invariably with head towards base and with no flocculence; shoots often killed by feeding of purplish brown nymphs with wax plates around body and along the middorsal line; the alternate host is *Picea* spp. (Balch and Underwood 1950; Underwood 1955).

Pineus strobi Htg. Districts: 1 to 7, 9 to 14, 16, 18, 19, and 21. Host species: *Pinus strobus* (65), *P. sylvestris* L. (3), *P. resinosa* (1). Collected: early May to late August. Comments: adelgids in masses of white cottony secretion on the undersides of branches and on the trunk; there is no alternate host (Doane 1961).

Pineus sylvestris Annand District: 4. Host species: *Pinus sylvestris* (1). Collected: March. Comments: a flocculent species collected on exposed roots in late March; no alternate host is known (Annand 1928). (This species was only recently identified in Ontario and may be a variant of *Pineus pini*.)

Key to Adelgid Galls on Spruce

1. Gall pineapple-shaped with gall-needles often short and thick but never modified to thin scales. 2

Gall elongate, cone-like, or appearing as a scraggly deformed twig. 4

2. Gall terminal on twig, small, pinkish or pale green; usually on *Picea mariana* ..... *Adelges strobilobius* Kalt:

Gall rarely terminal, foliage green except closed mouths of cells red-brown to purple. 3

3. Gall-needles variable but usually not less than ⅓ normal length; nymphs pale yellow with fine white pulverulency. ..... *Adelges abietis* Linn.

Gall-needles less than ⅓ normal length; nymphs reddish with abundant flocculence. ..... *Adelges lariciatus* (Patch)

4. Gall cone-like, needles modified to thin scales. ..... *Pineus pinifoliae* Fitch

Gall elongate or appearing as a scraggly twig, gall-needles not scale-like. 5

5. Gall-needles radiating to expose gall-surface with lateral joining of tissue between swollen needle bases; gall terminal on twig. 6

Gall-needles more or less obscuring gall-surface and with no lateral joining of tissue between swollen bases of needles; mature galls often elongate and appearing as scraggly twigs. ..... *Pineus similis* Gill.

6. On *Picea mariana,* rarely others. ..... *Pineus floccus* (Patch)

On *Picea pungens.* ..... *Adelges cooleyi* Gill

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PHENOLOGY OF EGG-LAYING OF THE CABBAGE MAGGOT, *HYLEMYA BRASSICAE* (BOUCHE) ON EARLY CABBAGE IN EASTERN ONTARIO[1]

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Abstract

Long-term studies at the Central Experimental Farm, Ottawa, showed that spring-generation adults of the cabbage maggot, *Hylemya brassicae* (Bouché) began to lay their eggs on about May 12, following the accumulation of 357 day-degrees above 40°F. This corresponded closely to the date of full bloom of wild Canada plum, *Prunus nigra* Ait., a common and conspicuous native tree. It also corresponded closely to the blossoming period of several species of wild serviceberries and first bloom of five winter hardy varieties of cultivated plum.

The average date of peak egg-laying was May 25. This corresponded closely to the period of full bloom of McIntosh and Cortland apples. Oviposition was greatest on calm, sunny days with intermittent cloud cover and daily maxima reaching into the low seventies.

* * * * * *

Introduction

From 1946 to 1962, the cabbage maggot, *Hylemya brassicae* (Bouché) was the subject of a series of investigations at Ottawa on chemical control, ecology, and host plant resistance (Harcourt *et al.*, 1952; Friend and Harcourt, 1956; Harcourt and Miles, 1959; Matthewman and Lyall, 1966). Incidental to these studies, the dates of egg-laying were recorded on 25 cabbage plants in the same test field for 15 years. The eggs were counted daily from early May to mid-June to determine dates on which egg-laying began, peak periods of oviposition, and total numbers laid. From 1959 to 1964, additional observations were made on the flowering dates of a number of wild and cultivated plants. In this paper, egg numbers have been correlated with weather data and also with plant blossoming phenomena that might be of use in the timing of chemical control applications. Such data take on new importance in the light of recent appeals stressing the need for new approaches to the strategy and tactics of insect control.

In the Ottawa area, cabbage damaged by maggots is attacked principally by *H. brassicae*. Most damage is done by first-generation maggots to the early crop, which is transplanted to the field about the middle of May. These maggots hatch from eggs laid chiefly in May and early June by flies emerging from overwintered puparia. The late crop is set out in late June and usually escapes severe injury.

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[1] Contribution Number 321 Research Station, Ottawa.

Since eggs that are laid in May and early June give rise to the maggots that do most damage to cabbage, the pattern of egg-laying and factors affecting it in this period are of prime interest.

Gibson and Treherne (1916), Brittain (1927), Miles (1951a,b, 1953, 1954), and Read (1958) described some effects of weather on egg-laying by *H. brassicae*. Schoene (1916), Caesar (1922), Glasgow (1925), Brittain (1927), Dustan (1932), and Fulton (1942) correlated activities of the insect with the blossoming of indicator plants. Timing control treatments for the cabbage maggot with the blossoming of cultivated varieties of European and native plums was recommended in Ontario as early as 1922 (Caesar, 1922).[2] However, this was applicable only to the warmer parts of the Province (viz, south-central and southwestern Ontario), where plums are grown commercially.

Materials and Methods

Study field and plants. The 25 cabbage plants were located in the long-established vegetable variety test field of the Ottawa Research Station, Central Experimental Farm. This consisted of six acres of fertile, well drained sandy loam in which were grown a large variety of vegetable crops, including a succession of crucifers. The study plants, variety Golden Acre, were transplanted to the field each year in early May, when they were about five inches tall, and set 12 inches apart in a single row between blocks of other crops. Location of the row varied from year to year but was usually within 150 feet of those of a previous year. A large apple orchard with grassy areas bordered the east side of the field, providing shelter for the flies.

Records on eggs. Most eggs were found on the soil surface within an inch of the stem, or against the stem itself in the narrow crevice formed between stem and soil; they were rarely found on the plant. Occasionally they were found in cracks of soil, or in hollows sheltered by lumps of soil up to two inches from the stem. They became mixed with the soil after heavy rains and were occasionally blown away by high winds.

Numbers of eggs were recorded daily beginning in early May. They were counted *in situ* and removed with a moistened brush. Records were continued to 15 June, when the eggs were usually no longer numerous.

Records on weather. Data on air temperature, sunshine, rainfall, and wind velocity were obtained from the Agrometerology Section, Plant Research Institute, which was stationed a few hundred yards to the south of the study area.

Records on plant blossoming. Records on the flowering dates of apples, and of cultivated plums and pear, were from orchards in the vicinity of the study field. Records on the flowering dates of wild plums and *Amelanchier* spp. were taken at several locations within a 10-mile radius of the Central Experimental Farm.

Species identities of eggs. Although *H. brassicae* was clearly the predominant species, many of the eggs recorded in late May or June were of *H. platura* (Meig.) and *H. florilega* (Zett.). For example, of 950 eggs collected from 12 May - 26 May in 1960, all were *H. brassicae,* and of 4,200 eggs examined in 1962, 96 percent of those collected to 31 May were *H. brassicae;* thereafter only 10 percent were *H. brassicae.*

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[2] When Caesar spoke of "native plums" he evidently meant cultivated varieties of *Prunus americana* Marsh. parentage.

Results and Discussion

Periodicities of egg numbers

Egg-laying began as early as 5 May, as late as 20 May, and on the average on 12 May (Table 1). It usually peaked during the last week of May. Fig. 1 shows that numbers began to rise rapidly about 17 May and to fall sharply at the end of the month. Only 27 percent of the total were found in June. Since just seven percent were found before 17 May and eight percent after 7 June, this three-week interval must be regarded as critical from the standpoint of control.

Egg numbers followed no definite pattern of intensity but some trends were noteworthy: high numbers were usually clustered into a period of nine or 10 days in years of average or light infestation; in years of heavy infestation, high numbers were spread over about three weeks (1951 and 1961) or five weeks (1957). About one-third of all eggs were laid in the four-day period 24 - 27 May (Table 1); the concept of a four-day peak period was therefore adopted.

Weather in relation to egg numbers

In the two months preceding first eggs. Temperature records were examined for March, April, and early May. A combination of weather factors was no doubt required to enable overwintered puparia in the soil to give rise to flies and for the latter to feed, mate and mature their eggs, but temperatures alone were important. The number of day-degrees accumulated from March 1 were related to the date in May on which the first eggs were found; when several basal temperatures were used, the mean number of day-degrees required in the 15 years were as follows:

32°F	36°F	40°F	45°F	50°F	55°F	60°F
653±15	489±12	357±10	238±7	151±6	91±5	51±4

In the week preceding first eggs. Weather in this week was not unusual. Daily maxima and minima, sunshine, wind velocities, and rainfall were almost normal.

On the day of first eggs. The first eggs were usually found on a clear spring day in a sudden warm spell. As a rule, the day was sunny and calm. Average maxima rose to 70.3°F from about 64°F in the four preceding days; average minima also rose, but only by two degrees. Daily highs varied from 60° to 80°F, although eggs were not uncommonly found on days with a maximum of less than 60° once egg-laying had begun.

Average wind velocity was 113 miles per 24 hours and sunshine, 9.3 hours. Rainfall was recorded only four times in the 15 years.

On the peak of egg-laying. Fifteen percent of the eggs were found on the peak date. Typically the day was calm, warm, and slightly cloudy, but not unduly hot or dry. Wind velocity averaged 97 miles per 24 hours. Maxima and minima averaged 71.3°F and 51.5°F. There were 6.7 hours of bright sunshine per day.

In the 4-day peak period. This period was usually warm and calm with normal sunshine and measurable rainfall. Maxima and minima averaged 72.3°F and 50.2°F. Mean wind velocity was 122 miles per 24 hours. Hours of bright sunshine averaged 7.9 per day.

TABLE I. Numbers of eggs of *Hylemya* spp. on 25 cabbage plants in the same test field, Ottawa, 1946-62.

Year	Number counted to 15 June	Average number per plant per day	First found	Peak day	Four day peak period[a]	Number counted in 4-day peak period	Number in 4-day peak period as a percentage of yearly total
1946	3,205	3.1	10 May	26 May	23-26 May	1,605	50.1
1947	1,621	1.5	20 May	6 June	3-6 June	719	44.4
1948	336	.3	13 May	28 May	26-29 May	127	37.8
1949	2,315	2.2	9 May	24 May	22-25 May	780	33.7
1950	2,638	2.5	20 May	29 May	29 May-1 June	966	36.6
1951	12,344	11.8	14 May	29 May	21-24 May	3,441	27.9
1952	7,119	6.8	8 May	23 May	26-29 May	2,532	35.6
1953	3,018	2.9	7 May	19 May	17-20 May	978	32.4
1954	2,358	2.2	13 May	21 May	18-21 May	858	36.4
1955	5,785	5.5	5 May	26 May	26-29 May	1,836	31.7
1957	15,281	14.7	5 May	26 May	28-31 May	2,856	18.7
1959	2,223	2.1	10 May	21 May	19-22 May	835	37.6
1960	3,339	3.2	11 May	19 May	18-21 May	1,422	42.6
1961	9,497	9.1	14 May	30 May	30 May-2 June	2,993	31.5
1962	4,915	4.7	16 May	20 May	17-20 May	1,675	34.1
Means	5,066	4.8	12 May	25 May	24-27 May	1,575	35.4

[a]Four days on which more eggs were counted than on any other four consecutive days.

In the total period. Eggs were laid in a great variety of weather, from days of below 60°F maximum temperature to those of above 90°F. High numbers of eggs were frequently found on days with the following average characteristics: maxima and minima, 70°F - 74°F and 47°F - 52°F; wind velocities, 97 - 135 miles per 24 hours; sunshine, 6.7 - 8.5 hours per day. Thus, air temperatures, wind velocity, and rainfall were important. Sunshine appeared to be somewhat less important; in fact, there was a suggestion that intermittent cloud cover was favourable. Very light rainfall was often favourable but heavy or continuous rainfall was not.

Periodicities of plant blossoming.

When the first eggs of *H. brassicae* were found, many wild and cultivated plants were in bloom. The most useful of these as indicators for the beginning of egg-laying were wild Canada plum, *Prunus nigra* Ait., and several wild service-

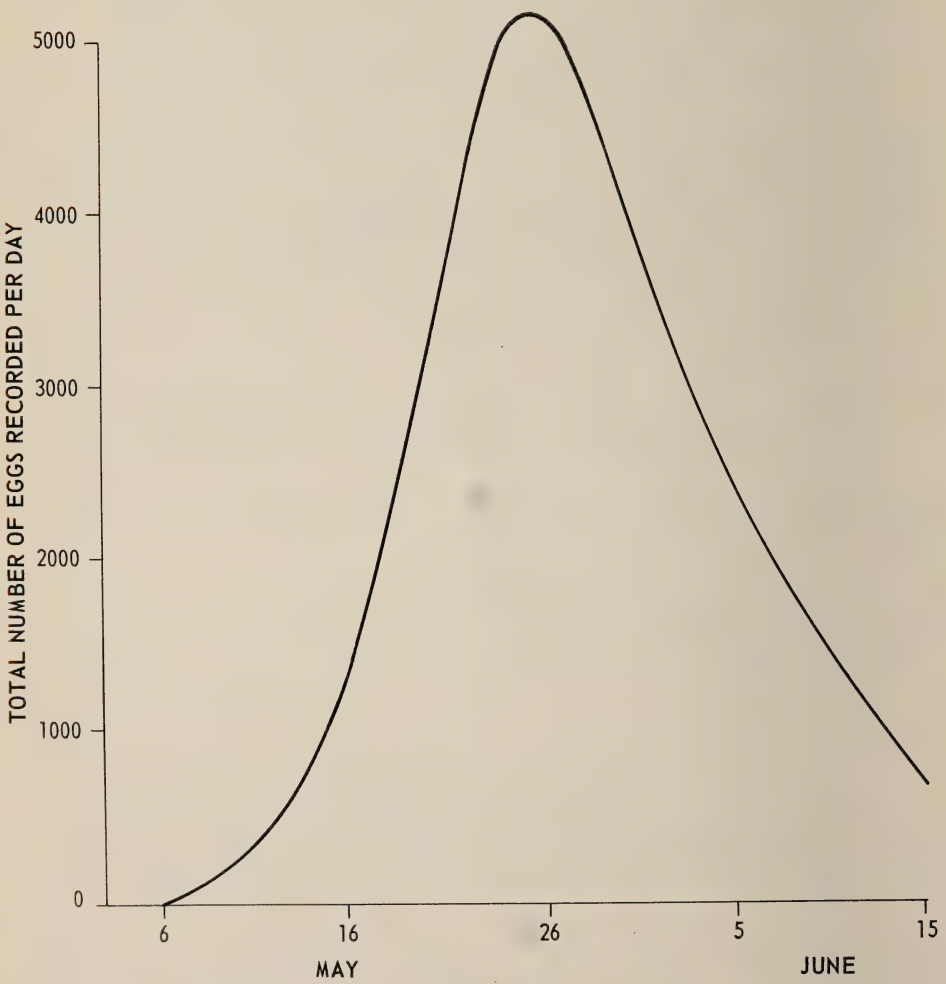

FIGURE I. Temporal pattern of egg-laying of *Hylemya* spp. at Ottawa, 1946-62. (Data smoothed by eye).

berries. When numbers of eggs were at their peak, McIntosh and Cortland apples were usually in full bloom and Flemish Beauty pear was at petal-fall.

Wild plums. P. nigra was especially reliable as a plant indicator for the first eggs. This tree is common in agricultural areas of eastern Ontario, is easily recognized when in bloom, and it often blooms suddenly and rather briefly. First bloom through petal fall from 1959 to 1963 averaged just eight days.

In the years 1959 to 1963, *P. nigra* was in full bloom[3] at numerous locations in and near Ottawa on 10, 10, 14, 16 and 14 May respectively. First eggs of *H. brassicae* were found on the same day as full bloom in 1959, 1961 and 1962, a day after full bloom in 1960, and two days before full bloom in 1963. Long-term records in the Herbarium of the Plant Research Institute suggest that wild *P. nigra* is usually in full bloom about 12 May in the Ottawa area, which was the average date on which the first eggs were found in this study.

P. nigra is common near Ottawa and throughout the agricultural areas of eastern and south-central Ontario. Many specimens were observed in the Ottawa Valley westward as far as Mattawa, eastward to the Quebec border, southward to Cornwall, and westward along the St. Lawrence River and Lake Ontario to Oshawa. Many specimens were also observed in the Gatineau Valley of Quebec as far north as Maniwaki.

P. americana Marsh. scarce in eastern Ontario (Groh and Senn, 1940). From observations in the present study it blooms from one to several days later than *P. nigra.*

Wild serviceberries. From 1959 to 1964 several species of serviceberries bloomed almost simultaneously with *P. nigra.* Although it was not easy to distinguish between some of the species, we concluded that *Amelanchier* as a group would serve as alternative indicators for the first eggs in areas near Ottawa where *P. nigra* was absent. In 1962, the sequence of blossoming was as follows: full bloom about a day before *P. nigra, A. arborea* (Michx.f.) Fern; on the same day as *P. nigra, A. laevis* Wieg. and *A. intermedia* Spach; about a day after *P. nigra, A. spicata* (Lam.) K. Koch and *A. humilis* Wieg.

Near Perth and Mattawa, Ontario, the following three species bloomed slightly later than *P. nigra: A. sanguinea* (Pursh) D.C., *A. stolonifera* Wieg., and *A. huronensis* Wieg.

Cultivated plums. Although European plums are not grown commercially in eastern Ontario, data of the Ottawa Reaserch Station were available on the blossoming of Assinaboine plum[4] and four winter-hardy hybrids. The relationship between first bloom and first eggs in the 15 years was as follows:

Average date of first eggs	Average dates of first blossoming of plums				
	Assiniboine	Grenville	Fiebling	Kahinta	Underwood
May 12	May 12	May 13	May 13	May 13	May 14
Correlation coefficient	.890**	.938**	.917**	.887**	.836**

**Significant at the 1% level.

[3] When 75 to 90 percent of the blossoms were open.

Cultivated apples and pear. The peak of egg-laying corresponded rather closely with the dates of full bloom of two varieties of apples and with petal fall of a variety of pear. The average dates of first bloom, full bloom, and petal fall[5] for the 15 years were respectively as follows: McIntosh 20, 24, and 28 May; Cortland, 20, 24, and 29 May; Flemish Beauty, 17, 21, and 25 May. The relationship between dates of peak egg-laying and those of full bloom (apple) and petal fall (pear) was as follows:

Average date of peak eggs	Average dates of full bloom or petal fall		
	Apples		Pear
	McIntosh	Cortland	Flemish Beauty
25 May	24 May	24 May	25 May
Correlation coefficient	.775**	.710**	.642*

*Significant at the 5% level; **Significant at the 1% level

Almost one-half of all eggs recorded were found during the blossoming periods of these two varieties of apples, and a fifth of them in four days at the height of blossoming.

It is perhaps significant that so many eggs were found when the apples were in bloom. That the flies are attracted to the blossoms of various plants is well known, e.g., wild mustard (Shoene, 1916), dandelions, white clover, marsh marigold (Caesar, 1922), and wild cherry (Brittain, 1927). Shoene (1916) stated that while apples are in bloom adults have frequently been taken with pollen clinging to the legs and chetae. According to Miles (1951a) the flies may depend on nectar-producing flowers for survival, and for this reason an intimate association may exist between the time of fly activity and the blossoming of shrubs and fruit trees. The pattern of egg-laying reported here was similar to that observed in a second field located near an orchard five miles south of Ottawa during the same years, but whether trends would have been different in the absence of fruit trees is, of course, impossible to judge.

No observations were made in soils other than sandy loam. Read (1958) found that spring-generation adults began to emerge much earlier in sandy loam areas than in clay loam areas, and that in general early planted rutabagas in the sandy loam areas and late planted rutabagas in the clay loam areas, were more severely damaged. The crops concerned in the present study are early cabbage, cauliflower, and radish, which at Ottawa and many other localities are planted in sandy soils. Planting in organic soil areas might well result in still different times of egg-laying.

Conclusions

Cultivated plums, long recommended as indicator plants for timing control programs against the cabbage maggot in the warmer parts of Ontario, would be effective at Ottawa as well if winter-hardy varieties were grown on a commercial scale. However, in their absence, wild Canada plum would serve as an accurate guide to the beginning of egg-laying. Wild serviceberries would be similarly

[4] A selection of *P. nigra* (Blair, 1950).

[5] When about 75 to 90 percent of the blossoms had dropped from the trees.

helpful. Full bloom of McIntosh and Cortland apples would be a useful indicator in judging the peak of egg-laying. It is speculated that cabbage and other crucifers transplanted to the field after May 31, would, in most years, escape the bulk of first-generation eggs.

Acknowledgements

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BAITED PLASTIC DRINKING STRAWS FOR STUDYING SOIL BIOTA[1]

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Abstract

Autoclavable, perforated drinking straws sealed at both ends and filled with pearl barley pellets coated with limestone and molasses, with or without pesticides, were moistened and placed vertically in field soil 5 cm from durum wheat plants. After 7, 21, 42 and 70 days microfaunal components adhering to, and inside the straws were counted. The succession of straw habitation was: fast moving Collembola, slower moving mites, then nematodes. Mites and nematodes bred, then decreased due to overpopulation or staling of the medium. Mites were able to thrive better than Collembola within the straws. There was a large increase in nematodes when mites were reduced by the acaricide, omite. The straws are cheap, inconspicuous, can be used for determining the mobility, vertical distribution, and antagonisms of the dominant microfaunal components, and permit measurement of efficacy of soil treatments against these components with time. They suffer from the disadvantage, however, that some microfaunal genera are not isolated, pellet debris makes organism counts difficult, and variations in soil texture and moisture can alter movement of organisms into straws.

The soil is a dynamic medium in which changes are related to both biotic and abiotic factors. Biota include the microfauna and microflora which are closely related in a complex manner and fluctuate seasonally with the crop, climate and agronomic practices. The microflora and microfauna are presently assessed by separate techniques. This paper describes a technique which provides a simple, quick and simultaneous assessment of soil biota and shows how it can be used to obtain evidence for antagonism between biotic types.

Materials and Methods

General Description of the Technique

The baiting device used consists of a perforated, autoclavable, plastic drinking straw containing non-viable pearl barley (Fig. 1). The straws are 15 cm long, 0.6 cm in diameter, and are perforated with 10 holes per cm by a zig-zag sewing machine. Each needle thrust makes two perforations, one in each wall of the straw. In each cm of wall there are five holes in two lines 0.5 cm apart. The five holes are in a zig-zag pattern with three holes in one line and two in the other. Each straw was sealed about 4 cm from the lower end with a Sealboy Elektro 700 sealer and a 9 cm-length filled with 1.2g of untreated or treated pearl barley or 1.9g uncoated glass beads above which a top heat seal was made across the straw. Two cm below the bottom heat seal, a fold was made in the straw at an angle of 135°, by a partial seal, for anchoring the straw in the soil. Above the top heat seal a coloured straw was inserted in the open end and fixed in place with a heat seal to permit color-coding of treatments. The treated barley was pelleted in a Wurster air suspension machine (Mills and Schreiber, 1971) in which 1200g pearl barley was

[1]Contribution No. 503, Research Station, Canada Department of Agriculture, Winnipeg, Manitoba.

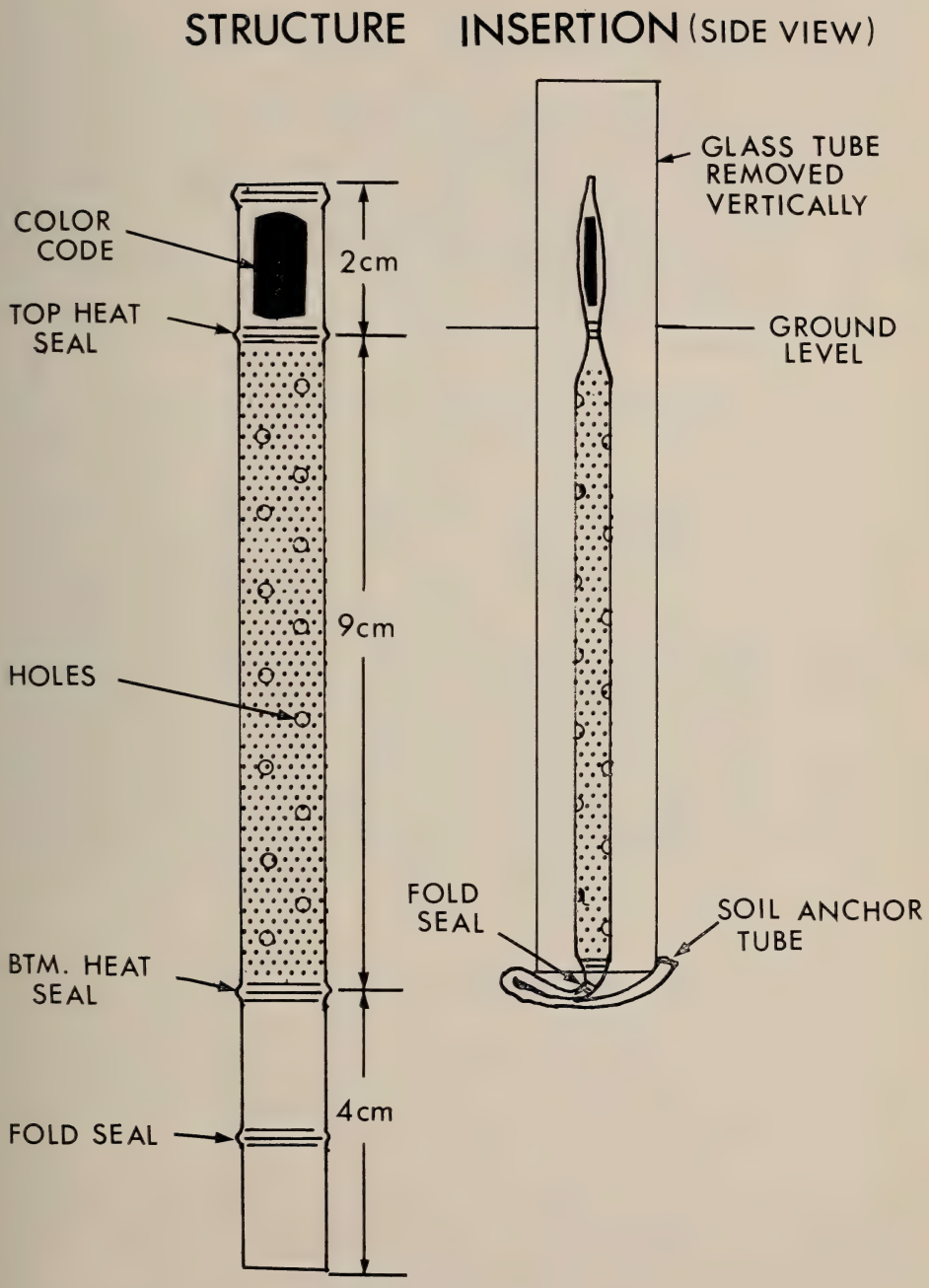

FIGURE 1. Diagramatic representation of the baiting device.

coated with a mixture of 740g ground limestone, 100 ml sugar beet molasses, 350 ml water and 100 g of a particular chemical. The uncoated glass beads were 3 mm in diameter and had been cleaned in 10% chromic acid and washed with water. Prior to vertical insertion in soil, the straws were shaken in sterile distilled water in test tubes for 5 sec. The water became cloudy from those straws containing coated barley indicating that the coatings were beginning to dissolve. The initial release of chemicals was thus obtained without relying on inadequate or variable soil moisture. Initially, straws were inserted into soil in a glass tube and when the tube was withdrawn from the soil the straw was held in place by the pressure of the soil on the bent straw outside the tube (Fig. 1). Later, straws were inserted directly into soil by pressing a 1 x 20 cm wooden rod onto the bent portion. Straws were pulled up after 7, 21, 42 or 70 days, and transferred to the laboratory in corked test tubes. The microfloral components were isolated on potato-dextrose-agar and the straws were stored individually in 70% alcohol. Counts were made of microfauna within the straws and in adherent soil, by using a binocular microscope (x12). Classification was to class of organism.

Experiment 1—Isolation of Dominant Microfaunal Components from Straws Containing Treated and Non-Treated Pearl Barley.—Sixteen replicates, each of nine randomized straw treatments, were placed in a crop of durum wheat at the 5th leaf stage on 14 June, 1971. Each replicate had three treatments in each of three rows. Straws were inserted at a distance of 5 cm from the row of plants in three rows across the field. Straws were spaced 30.5 cm (1 ft.) apart and replicate lots were 91.5 cm apart. Replicates 1-4 were removed after 7 days and subsequent groups of four replicates were removed after 21, 42 and 70 days. Treatments used were pearl barley, pearl barley plus molasses plus limestone, and pearl barley plus molasses plus limestone plus 100g of one of the following: *Atrazine* 80WP (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine), (herbicide), CIBA-Geigy Co., Montréal, Québec; *Benlate* (methyl 1-[butyl-carbomyl]-2-benzimidazole carbamate 50%), (fungicide), Dupont de Nemours & Co. Inc., Wilmington, Delaware; *Diazinon* 50WP (diethyl-2-isopropyl-6-methyl-4-pyrimidinyl phosphorothionate), (insecticide), CIBA-Geigy Co.,; *Omite* 30W (2-[P-T-butylphenoxy] cyclohexyl propargyl sulphite), (acaricide), Uniroyal Chemical Division, Elmira, Ontario; *Panogen Px* (methyl mercury dicyandiamide 0.9%), (fungicide), Nor-Am Agricultural Products Inc., Woodstock, Illinois; *Vitavax* 75WP (5,6-dihydro-2-methy-1, 4-oxathiin-3-carboxanilide), (fungicide), Uniroyal; and α *cellulose* (Sigma Chemical Co., St. Louis, Missouri).

Experiment 2.—Isolation of Microfauna from Straws containing Glass Beads and Pearl Barley.—On 6 August 1971 five replicates, each of nine straws, were placed, when the crop was in the flag leaf stage, in the same field as Experiment 1. The three treatments were pearl barley, pearl barley coated with limestone and molasses, and glass beads. The experimental design was similar to that of Experiment 1. Completed straws were autoclaved at 15 lb. per sq. in. for 20 min. Straws remained in soil for 22 days and were then examined as in Experiment 1.

RESULTS.—Experiment 1.—Dominant Microfaunal Components.—The organisms encountered most frequently were mites, nematodes, and Collembola; also found were fly and beetle larvae, and enchytraeid worms. The mites observed were mainly Astigmata and very occasionally, Mesostigmata.

The pattern of microfaunal counts within the straws (Table 1) was similar to that of the total microfauna both within and adherent to the straws. Counts of microfauna on the outside of straws and in adherent soil are therefore unnecessary.

The straws were inhabited by successions of Collembola, mites and nematodes.

I. The Collembola were very mobile and occupied the straws within 3 days. They reached a peak in numbers after 7 days and were much decreased after 21 days.

II. The mites, which were generally slow moving Astigmata and present after 7 days, reached a maximum by 42 days and decreased by 70 days.

III. The nematodes, which were also slower moving, increased in numbers as the mites decreased.

Collembola were attracted or arrested by molasses and by cellulose but not by pearl barley alone or by pesticide-treated pearl barley. Mite populations were highest on cellulose and nematode populations were highest on the omite treatment.

The fungi isolated within and adherent to the straws were mainly those present on the original pearl barley (Fig. 2). *Gliocladium solani* (Hartig) Petch, *G. roseum* Bain. and *Penicillium crustosum* Thom. were most abundant. *Absidia lichtheimii* (Lucet and Constantin) Lendner, *P. patulum* Bain., *Fusarium* sp., *Rhizopus* sp. and *Trichoderma* sp. also occurred. The genera isolated were not significantly changed by different treatments.

Experiment 2.—Comparison of Glass Beads and Pearl Barley as Straw Inclusions. —Glass beads were unsatisfactory for retaining microfaunal components when compared to molasses-coated or uncoated pearl barley (Table 2) in particular, fewer mites occurred on the glass beads.

The number of mites within pearl barley straws after 22 days in a mature durum wheat field was lower than in similar straws in the same field close to young plants after a similar period (Table 1). Changes in moisture, root exudates and temperature during the experimental periods may affect counts.

DISCUSSION.—The rise in mite population in the straws was coincident with a fall of Collembola suggesting that the former were able to thrive better than Collembola within the straws. The decrease in mite numbers was probably caused by exhaustion of nutrients, overpopulation, or production of noxious metabolic

TABLE I. Dominant microfaunal components[a] isolated from within straws that contained treated and non-treated pearl barley in a durum wheat field; (straws were pulled up and examined after 7, 21, 42 and 70 days in soil).

Treatment	Collembola				Mites				Nematodes			
Time (days)	7	21	42	70	7	21	42	70	7	21	42	70
Pearl barley	19	0	0	0	0	296	588	420	0	0	6	194
Molasses	344	20	0	2	0	182	919	363	0	1	30	394
Cellulose	128	1	0	2	0	348	1561	875	0	2	47	12
Panogen	4	0	0	0	1	32	40	114	0	0	1	258
Benlate	2	5	0	0	1	13	1	0	0	0	3	0
Vitavax	0	0	0	0	0	168	803	247	0	0	0	7
Omite	0	2	0	0	0	60	46	2	0	35	1151	76
Diazinon	0	0	0	0	0	0	0	0	0	0	0	2
Atrazine	6	2	0	0	0	94	253	294	0	0	24	3

[a]Mean number within four straws.

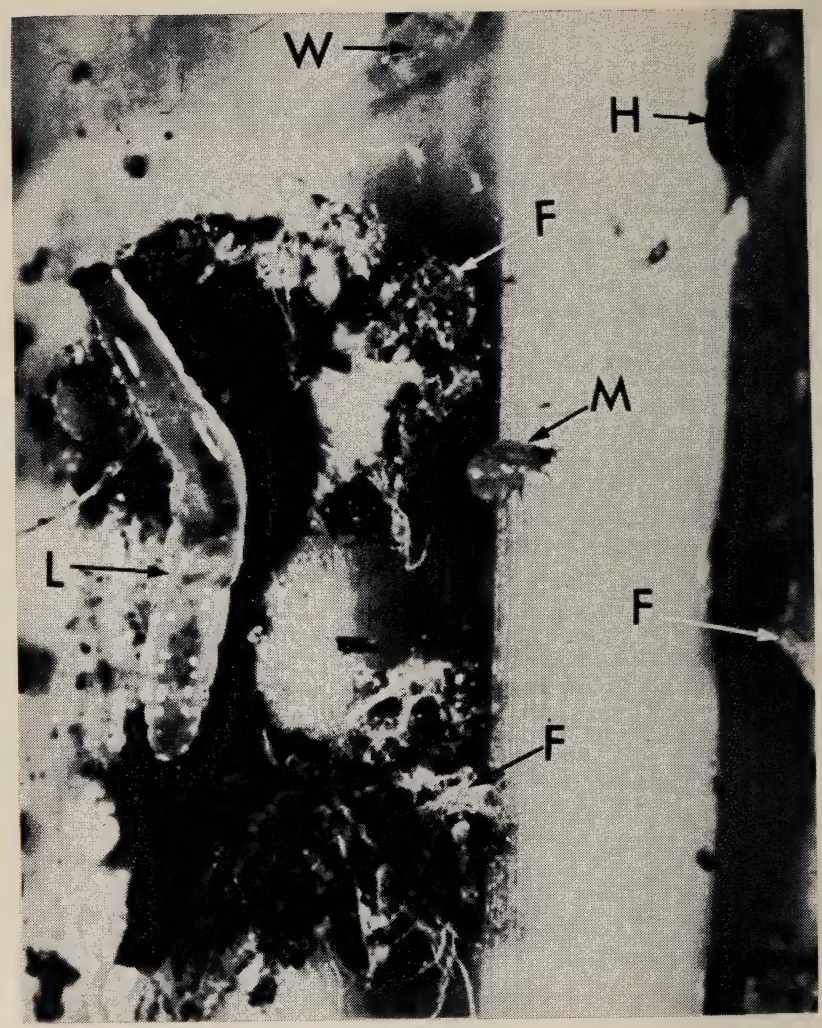

FIGURE 2. Photograph of straw removed from soil after 14 days showing *Penicillium* and other fungi (F) growing out of holes, and beetle larva (L), mite (M) and enchytraeid worm (W) specimens. H is an unoccupied hole. (x 30).

TABLE II. Counts of microfauna[a] on glass beads and pearl barley in straws adjacent to mature plants of durum wheat.

	glass beads	pearl barley	pearl barley + molasses + limestone
Collembola	0	6	4
Mites	4	33	43
Nematodes	1	23	8

[a]Mean number (within + adherent) per 15 straws.

products staling the environment. Nematodes, unlike mites, did not occur with Collembola although both nematodes and mites appear to move at about the same rate. Collembola are known (Gilmore, 1970) to actively prey and assimilate nematodes and this could explain why Collembola and nematodes were not observed together. The increase in nematode populations with omite is likely due to reduction of competition by suppression of mites and to removal of Collembola. Nematode populations in straws that contained Panogen remained high, unlike most other pesticides, suggesting that nematodes can tolerate Panogen.

Most of the microfaunal components isolated from the straws were microfaunal grazers attracted or arrested by the molasses or fungi occurring on the straws. More work is needed to determine whether the build-up of population on the pellets is the result of a definite attraction by an attractant chemical causing insects to make orientated movements towards its source or the result of arrestant action by an arrestant chemical which causes insects to aggregate in contact with it (Dethier *et al.* 1960). It is conceivable that the increase of mites on cellulose (Table 1) may be related to increased cellulolytic fungi.

RECOMMENDATIONS.—It is recommended that the straws be used for approximately 14 days in soil, thus the numbers attracted or arrested are separated from the breeding populations which occur later. Only components within straws should be counted and at least 12 replicates should be used to allow for soil heterogeneity.

ADVANTAGES AND DISADVANTAGES OF THE STRAW ISOLATION TECHNIQUE.—Advantages include: Straws are cheap and inconspicuous in survey sites where there might be public interference such as along roadside verges, or in garbage dumps. Counts can be quickly made and the contents of a straw do not have to be run through an extractor prior to counting. The technique provides a quick estimate of microfaunal changes in selected soil areas. The vertical distribution of microfauna in soil can be assessed when straws are attached to long rods. The techniques can also be used to trap live specimens for laboratory antagonism studies and for investigating antagonisms in the field. For example, individual fungi can be inoculated onto pearl barley in sterile straws and used as baits. Likewise, naturally infested cereal seed without embryos can be used. The straws can also be used to determine the efficiency of insecticidal, nematocidal or sterilization treatments in soil over a period of time. For example, counts of residual microfauna in fumigated greenhouse beds can readily be made.

Disadvantages include: Debris renders accurate counts of nematodes difficult, the procedure gives minimal numbers. All microfauna, particularly larger types such as earthworms, do not penetrate the straws; earthworms did occur, however, on the outside of straws in preliminary experiments in woodland. Variations in soil texture and moisture can alter the progress of organisms into the straws.

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NOTES ON THE BIOLOGY OF THE ALFALFA WEEVIL, *HYPERA POSTICA* (GYLLENHAL) (COLEOPTERA: CURCULIONIDAE) IN SOUTHERN ONTARIO

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Abstract

The life history, habits and seasonal history of the alfalfa weevil, *Hypera postica* (Gyllenhal) are outlined for Ontario. There is one generation a year. The adults emerge from hibernation in early spring and deposit eggs within the stems of alfalfa. The immature stages develop mainly during a period of 6 to 8 weeks in spring and early summer on the first growth of alfalfa. At this time, the egg, larval and pupal stages complete development in 8 - 12, 10 - 14, and 6 - 10 days, respectively. In 1971, in eastern Ontario, peak periods were as follows: eggs, May 31 to June 30; larvae, June 17 to July 7; and pupae, July 2 to July 13; corresponding peaks occurred three to four weeks earlier in southwestern Ontario.

* * * * * *

Introduction

The alfalfa weevil, *Hypera postica* (Gyllenhal), is one of the most destructive and widespread pests of alfalfa in North America. The crop is attacked by the adults and the larvae but most of the damage results from larval feeding on the buds and leaves. The insect is primarily a pest of the first growth; however, following harvest, sufficient larvae may remain in the field to damage the early second growth. When heavily damaged, the crop takes on a greyish or frosted appearance.

A European species, *H. postica* was first detected on this continent in 1904 in the state of Utah (Titus, 1910). It is now established throughout most of the United States where it is considered to be a major agricultural pest (Cochran 1966, 1968). In 1954, it was recorded for the first time in Canada, in Alberta (Hobbs, 1954) and Saskatchewan (McMahon, *et al.* 1954), and in 1967 MacLachlan (1967) reported it from southwestern Ontario. In 1968, high populations were found in Quebec near Lake Champlain (Perron 1969). The insect has spread rapidly through the main agricultural areas of Ontario since 1967, being found in 40 counties by 1970 (Goble, 1971), and has reached epidemic proportions in some localized areas. Studies on the ecology of the alfalfa weevil were initiated at Harrow, Ontario in 1969 and at Ottawa in 1970; this paper outlines its life history, habits and seasonal history.

Life History and Habits

Although the immature stages of *H. postica* may be found in alfalfa almost throughout the growing season, high densities of the insect are confined to a period of 6 to 8 weeks in the spring and early summer; hence, the duration of the various stages given below refer to that seasonal period.

The eggs (Fig. 1) are oval and bright yellow in colour, each measuring about 0.56 mm in length and 0.37 mm in diameter. At the time of oviposition the female chews a hole in the host stem and deposits her eggs in clusters containing as many as 30, or more. The puncture is then plugged with mascerated plant tissue. The eggs turn yellowish-brown and just before hatching the larval head capsule may be seen through the chorion. The incubation period varies from 8 to 12 days.

The newly hatched larvae may remain in the host stem for a short time before crawling to the terminal foliage. The first- and second-instar larvae feed largely on the unopened florets where they are often completely hidden. The older larvae feed on both the buds and the leaves but leaf feeding is more apparent and constitutes the main food source during the fourth instar; they feed between the veins, giving the leaves a characteristic skeletonized appearance (Fig. 2). The larvae pass through four instars in 10 to 14 days. Larvae of the first, second and early third instars are yellowish-white with a black head capsule. The late third- and fourth-instar larvae are bright green with a prominent white dorsal stripe and the head capsule of the fourth instar is brown. Fully grown larvae (Fig. 3) average about 9.0 mm in length. They construct their cocoons (Fig. 4) on the upper parts of the host plant.

Spinning of the cocoon is followed by about two days of quiescence making the pre-pupal period. The pupa (Fig. 5) is pale green with dark green appendages and measures about 6.0 mm in length; it transforms to the adult stage in 6 to 10 days (Fig. 6).

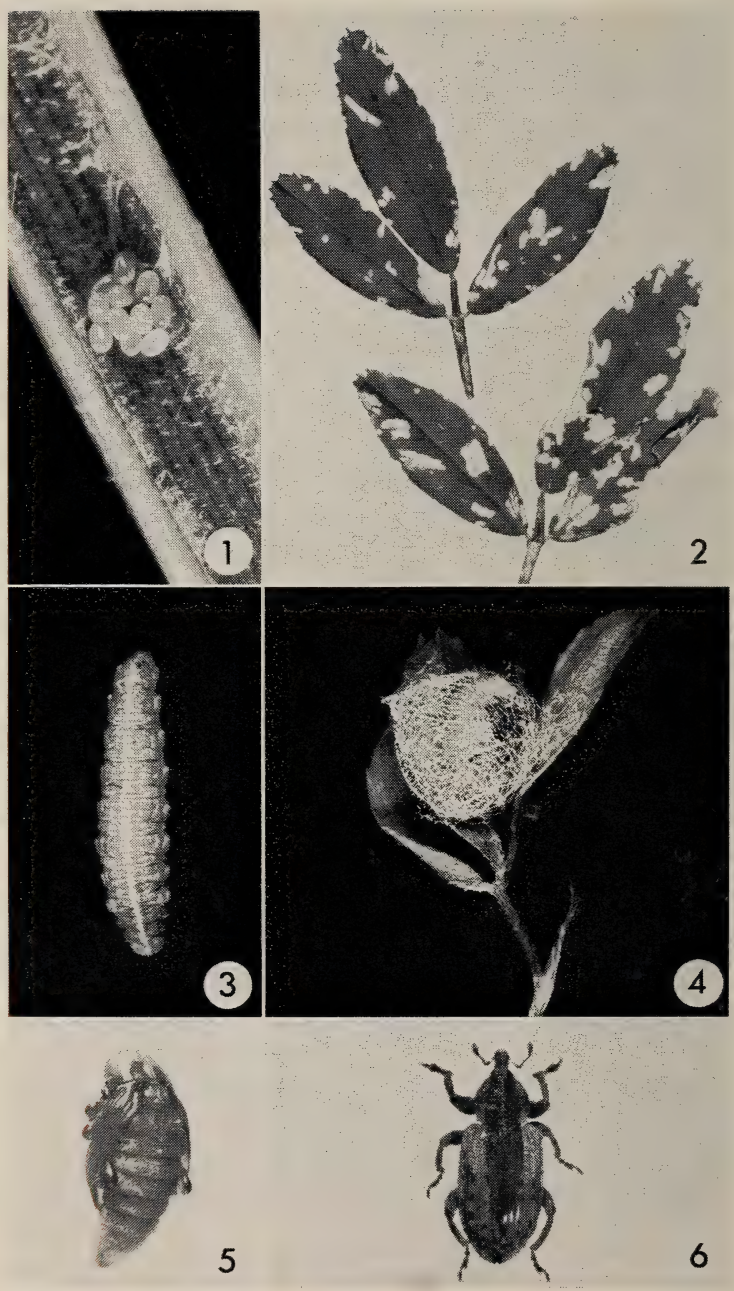
The new adults feed voraciously for about three weeks before entering a period of aestivation. They chew the leaves from the margins inwards creating narrow longitudinal notches which produce a ragged appearance; the stem epidermis is eaten away in irregular patches. Activity is resumed in the late fall when they feed, mate and lay a few eggs before the approach of cold weather forces them into hibernation. Overwintered adults become active in early spring and resume egg laying in the first growth of alfalfa.

Seasonal History

Seasonal history events discussed here are from observations in eastern Ontario; however, the pattern of development throughout Ontario appears to be similar, differing only in time. At Harrow, in extreme southwestern Ontario, peak periods of development of the various stages precede those at Ottawa by three to four weeks.

There is one generation a year throughout the province. At Ottawa, the adults become active in late April and begin to oviposit about mid-May. Figure 7 shows the seasonal development trend for immature stages; the curves are based on field counts taken at three to seven day intervals in 1971, and the numbers of each stage, at each count, are based on 32 samples of 12 stems of alfalfa taken at random from a quarter-acre plot. The peak period for each stage was: egg, May 31 to June 30; larvae, June 17 to July 7; and pupae, July 2 to July 13. On July 2, when the highest larval densities occurred, about 70% of them were in the late third or the fourth instar and about 10% of the larval population had already spun cocoons.

Overwintered adults still alive at mid-summer appear to be inactive during extremely hot periods. Eggs are laid intermittently during July and early August and then increase toward the end of August or early September. The larval populations resulting from these eggs are usually small and cause no noticeable damage.



FIGURES 1 - 6. The alfalfa weevil. 1: eggs in dissected stem. 2: leaves showing larval feeding. 3: fourth-instar larva. 4: cocoon. 5: pupa, dorsal aspect. 6: adult.

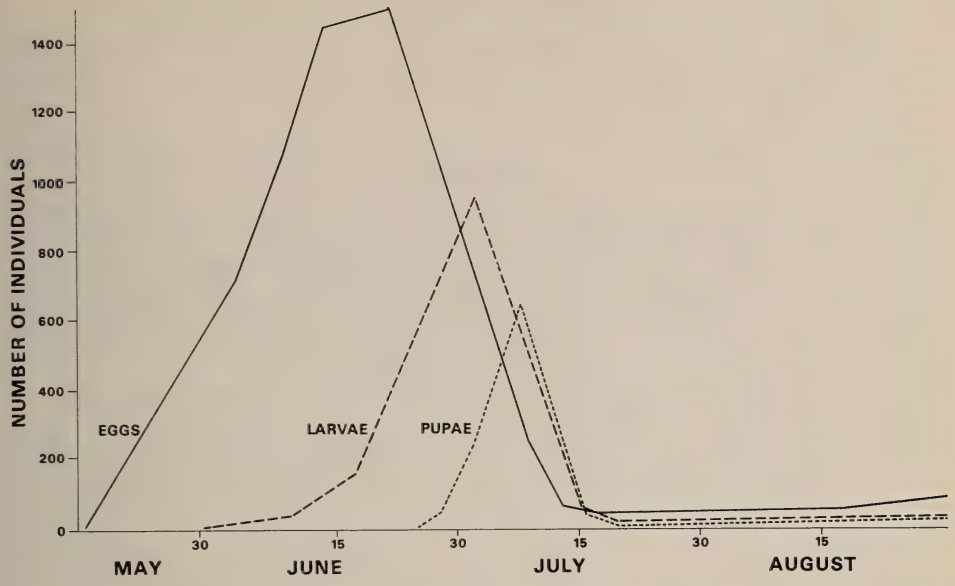


FIGURE 7. Seasonal development of the alfalfa weevil in eastern Ontario, 1971, based on the number of each stage per 384 stems at different times during May to August.

Control in Ontario

Crop management

The Ontario Department of Agriculture and Food (1971) recommends cutting alfalfa in the early flower stage for best quality forage; early harvest of the first crop, just before the first bloom opens, is also recommended for prevention of serious damage by the weevil. The insect is well synchronized with its host and by the time the first flowers open most of its eggs have been laid and larvae are developing rapidly in the buds. Precise timing of the first harvest can destroy significant numbers of larvae. This method of control may be limited by two factors, the growers ability to meet the harvest deadline, and wet weather. At present the only reliable alternative is chemical control. The O.D.A.F. publication 296 lists five registered pesticides for emergency control and advises on their use.

Biological

Suppression of the alfalfa weevil by importation and release of parasitoids has been attempted in the United States and Canada. Several species have become established and have spread with the weevil. An egg parasitoid, *Pattason luna* (Girault) and a larval parasitoid *Bathyplectus curculionis* (Thompson) were reared from the weevil at Harrow; these and another larval parasitoid, *Tetrastichus incertus* Ratzeburg, were reared commonly at Ottawa.

To date, in the absence of quantitative multifactor studies there is no conclusive evidence that parasitoids effectively suppress alfalfa weevil populations.

Acknowledgements

The authors express their thanks to Drs. D. G. Harcourt and M. K. Mukerji, Canada Department Agriculture, Research Station, Ottawa, Ontario for their constructive criticism of the manuscript.

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THE HAEMOCYTES OF *HYPODERMA* (DIPTERA: OESTRIDAE)

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Abstract

Six types of haemocytes are found in the cattle grubs, *Hypoderma lineatum* and *H. bovis:* prohaemocytes, plasmatocytes, granular haemocytes, adipohaemocytes, granulo-adipohaemocytes and a new type of haemocyte. Using phase contrast microscopy the cells were classified on the basis of their morphology (shape, size and nuclear cytoplasmic ratios), occurrence, histochemistry and physiology (including phagocytosis, motility, mitotic activity, in vitro culture, temperature effects on the cells and changes in the proportion of cell types at pre-pupation as well as during repeated bleeding.

* * * * * *

Introduction

Reviews of work on the haemocytes of insects have been given by Wigglesworth (1959) and Jones (1962), but no work appears to have been published on the haemocytes of *Hypoderma lineatum* and *H. bovis,* the cattle grubs.

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* These observations were included in a thesis accepted by the University of Liverpool, in partial fulfillment of the requirements for a degree of Doctor of Philosophy.

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It was the purpose of this study to describe and classify the different types of haemocytes found in the main developmental stages of these two species of *Hypoderma*.

Materials and Methods

A total of 83 individuals (13 first instar, 4 second instar and 54 third instar larvae, 6 pupae and 6 adults) were used in the study.

First instar larvae were obtained from the oesophagi and spinal epidural fat of cattle slaughtered at the Stanley Abattoir, Liverpool, England; second and third instar larvae were dissected from fresh hides at the Liverpool depot of the Merseyside Hides and Skins Association. The pupae were obtained from Dr. J. Weintraub, Canada Department of Agriculture, Research Station, Lethbridge, Alberta, Canada, and adults were reared from some of these pupae.

Haemolymph was collected as follows: the anterior and posterior portions of the larvae and the ptilinal sac of the pupae and adults were pierced with a needle and the haemolymph allowed to flow freely. The first two drops were used for other experiments on the pH and cell counts (which will be described elsewhere). Sealed coverslip preparations were then made from the next four drops of exuding haemolymph, one drop being left undiluted while one drop each of 2% lacto-aceto-orcein, 0.9% saline solution and oil-red-0 (Pearse, 1961) was added to the other three drops. The fresh wet films of haemolymph were examined with a Zeiss phase contrast microscope and photographs of the living haemocytes were taken with a camera attachment. Thick and thin smears of haemolymph were stained with Leishman's stain. Histochemical tests were also carried out on the haemocytes and these results will be published separately. The cells in stained sections were photographed under a Zeiss light microscope. Scale = 10μ.

Classification of Terms Used

The terms prohaemocytes, plasmatocytes, granular haemocytes and adipohaemocytes are used as by Jones (1962).

Plasmato-adipohaemocytes represent a transitional stage between plasmatocytes and adipohaemocytes.

Granulo-adipohaemocytes possess characteristics of both granular haemocytes (granules) and adipohaemocytes (fat), but because of their distinct morphology, physiology and occurrence in all the stages of development they are classified as a separate type of haemocyte.

There is also a new type of haemocyte which requires separate discussion and will be described in a publication elsewhere, (see Fig. 9A, B, C in the text).

Results

I. *Prohaemocytes*

(a) *General Morphology*

These cells are round or ovoid, measuring 2.5-11.6 u in diameter with a nucleus 1.7-7.0 u in diameter and an average nuclear cytoplasmic ratio of 0.6 (Table 1, Figs. 1, 9B) Amoeboid forms are also sometimes present.

In fresh sealed coverslip preparations, the cytoplasm appears greyish-green and may have finely granular inclusions or vacuoles. Many of the prohaemocytes observed have either filipodia or pseudopodia (Fig. 1). The nucleus is usually large and dense (Fig. 9B).

In thick smears stained with Leishman's, the cytoplasm appears as a blue band around a purple nucleus. In stained paraffin sections several prohaemocytes were observed with clear nuclei which contained scattered chromatin granules.

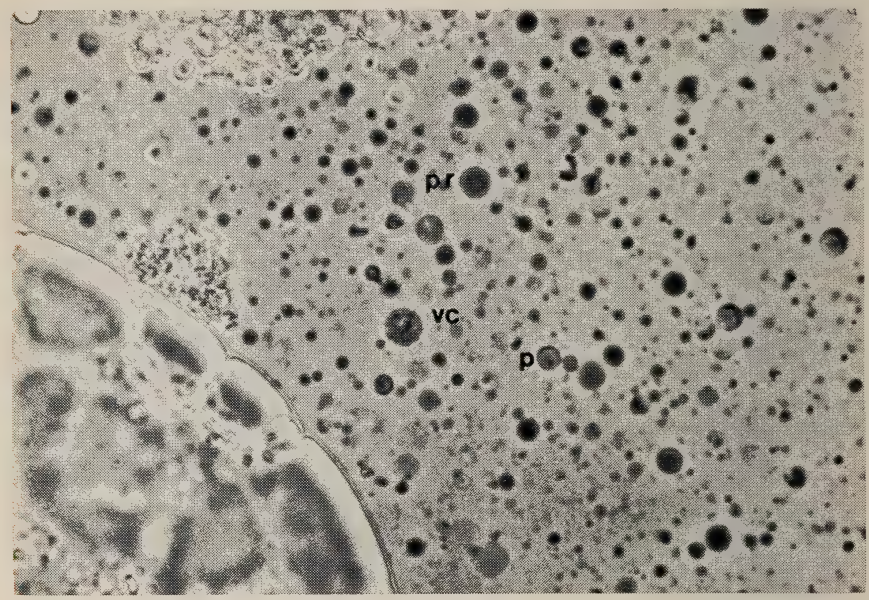

FIGURE 1. Portion of new cell type of *Hypoderma* showing prohaemocytes (pr), plasmatocytes (p) vacuolated cells (vc) and cell inclusions flowing from the cell into the plasma.

(b) *Occurrence*

Prohaemocytes occur in all the developmental stages of *Hypoderma* (Table 1), reaching their maximum numbers in the adult.

TABLE I. Morphology and patterns of development of types of haemocytes during the first instar larva to the adult of *Hypoderma bovis* and *lineatum*

Cell types	Range (u)	Nuclear Cytoplasmic ratio (N/C)	Mitotic activity	Instar in which cell first appears	Peak cell numbers
Prohaemocytes	2.5 - 11.6	0.6	—	First Instar	Adult
Plasmatocyte	2.5 - 28.8	0.3	+	First Instar	Adult
Granular haemocyte	6.5 - 26.0	0.3	+	First Instar	Variable
Granulo-adipohaemocyte	18.0 - 34.9	0.4	—	First Instar	Early Third Instar
Adipohaemocyte	8.0 - 34.9	0.6	+	First Instar	Third Instar

(c) *Behaviour*

Prohaemocytes are motile and phagocytic. They move by pseudopodia or by rapid extrusions and withdrawals of the filipodia. They were seen engulfing bacteria and small particles. They also accumulate large numbers of granules within the cytoplasm during moulting, thus developing into granular haemocytes (see Fig. 7H). Prohaemocytes were observed in groups of 2-7, especially during repeated bleeding of third instar larvae. This may indicate an increased stickiness of the cell membrane under these circumstances. They also become very numerous during repeated bleeding and in the pupal and adult stages. During the development of prohaemocytes, the transitional forms closely resemble young plasmatocytes, making it difficult to distinguish between the two.

2. *Plasmatocytes*

(a) *General Morphology*

These cells are polymorphic and may be round (Fig. 2B, C), ovoid (Fig. 2B, D), fusiform (Fig. 2E, F) or amoeboid (Fig. 2A, G, H). The round or oval forms may have a smooth outline or one or more filipodia. Some round plasmatocytes extend one or two pseudopodia (Fig. 2A, G, H), while degenerating round forms possess numerous bulbous (Fig. 2I) or spike-like cytoplasmic processes (Fig. 3A). The fusiform cells observed in the larvae (Fig. 2E, F) pupa and adult had uni- and bi-polar filaments.

The fusiform cells measure 43-120 u with a nuclear diameter of 4.9 u. The other cells measure 2.5-28.8 u and with a nucleus 0.8-7.5 u in diameter (Table 1). The average nuclear cytoplasmic ratio of these cells is 0.3. Plasmatocytes in the first instar larvae are generally larger than those in the other developmental stages.

The cytoplasm is greyish-green in fresh coverslip preparations seen by phase contrast microscopy. It may be homogenous (Fig. 2C) or granular (Fig. 2B, D). Fat globules are scattered through the cytoplasm and granules are present either close to the nucleus or distributed through the cytoplasm (Fig. 3B, F). As the fat inclusions gradually accumulate, the cells become plasmato-adipohaemocytes (Fig. 6A). The nucleus is usually round and granular, and may or may not have a distinct nucleolus. The chromatin granules stain well with 2% lacto-acetin-orcein.

In smears stained with Leishman's, the cytoplasm is usually basophilic, and reticulated or vacuolated. The nucleus stains pink or purple and contains chromatin granules. There are single, bi- and multinucleate forms.

(b) *Occurrence*

Round and oval plasmatocytes were seen in all developmental stages with maximum numbers in the adult (Table 1). Spiky forms were seen in larvae 24 hours before the formation of the prepupa, and in a four-week-old wet coverslip preparation of haemolymph taken from the third instar larva (Fig. 3A). Fusiform and amoeboid forms occurred in the late third instar larva (especially prior to prepupal formation) and in the pupa.

(c) *Behaviour*

Plasmatocytes with filaments are actively motile and phagocytic. Long individual filaments with disc-shaped sticky ends (see Fig. 2G) were seen extending into the plasma, each filament displaying searching and probing motions.

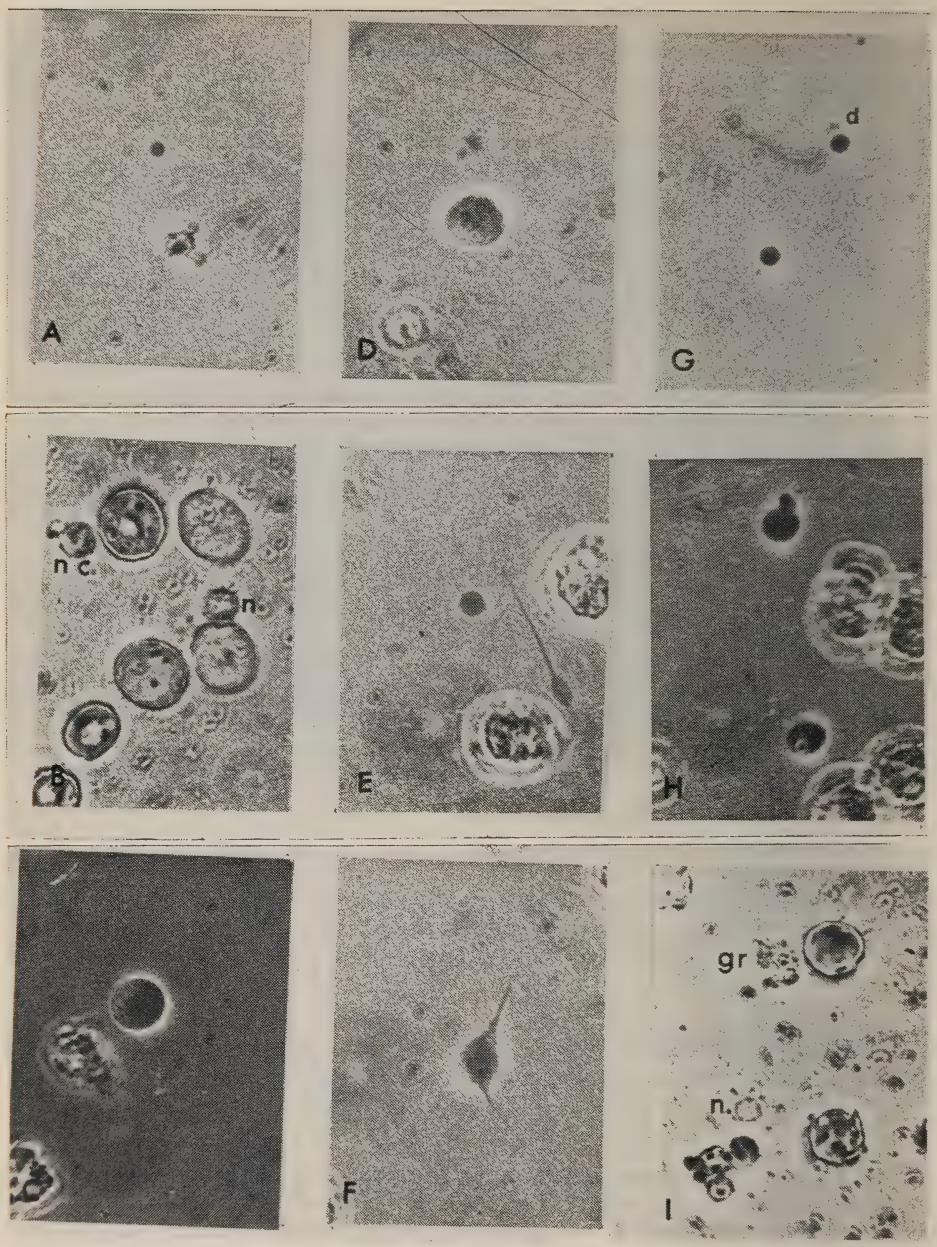

FIGURE 2. Haemocytes of *Hypoderma* larva showing:—A. Small round, amoeboid plasmatocyte, third instar larva; B. Round and oval plasmatocytes, free nucleus (n), nucleus and cytoplasm (nc), first instar larva; C. Round plasmatocyte (and two adipohaemocytes out of focus), third instar larva; D. Oval plasmatocyte, third instar larva; E. Round and unipolar plasmatocyte (two adipohaemocytes out of focus), third instar larva; F. Bipolar plasmatocyte, third instar larva; G. Two round, small plasmatocytes, one with disc-shaped cytoplasmic extension (d), third instar larva; H. Oval and amoeboid plasmatocytes, (four adipohaemocytes out of focus), third instar larva; I. Two round plasmatocytes, granular haemocyte (gr), degenerating plasmatocyte with bulbous cytoplasmic process, and free nucleus (n), first instar larva.

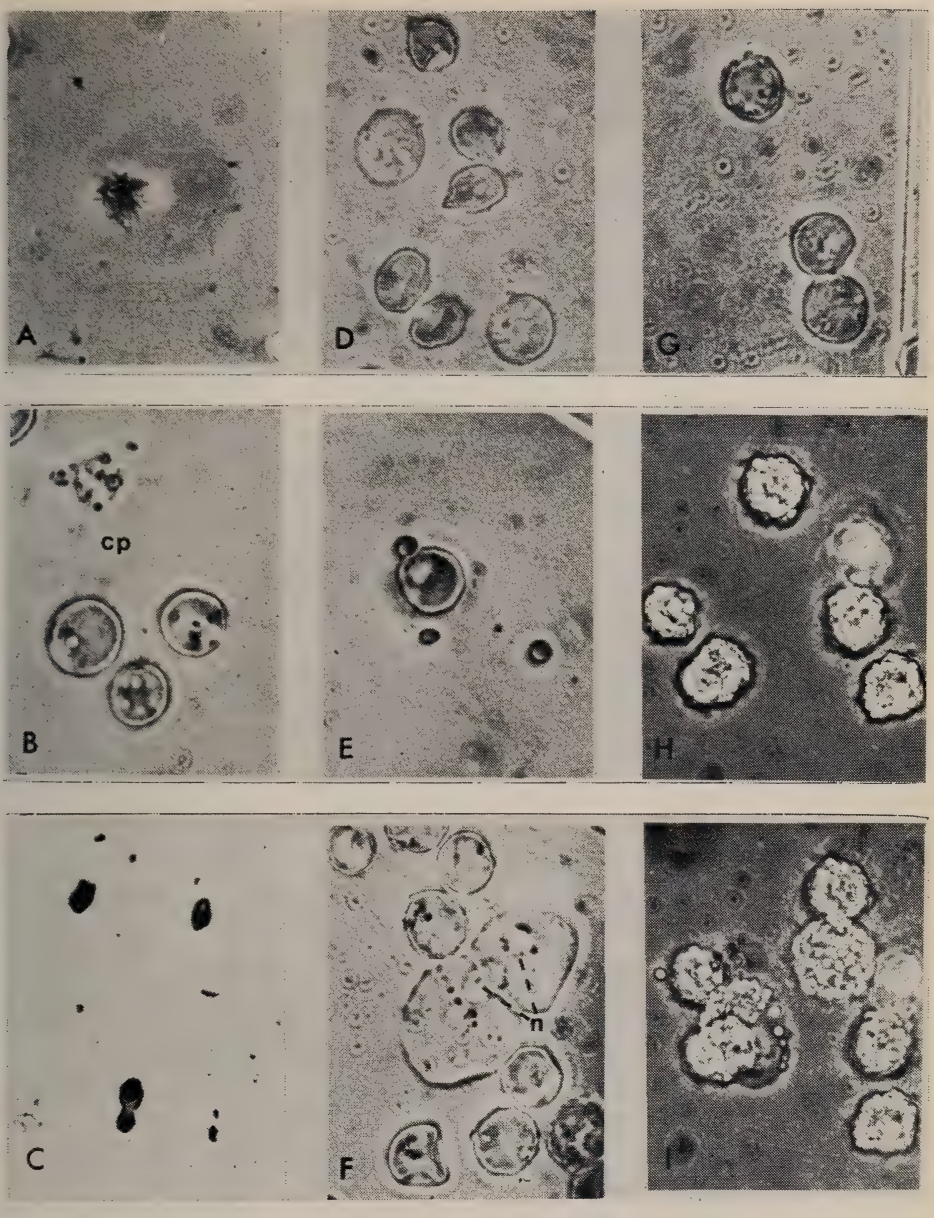

FIGURE 3. Haemocytes of *Hypoderma* larva showing:—A. Spiked plasmatocyte from four-week old *in vitro* preparation, third instar larva; B. Three round plasmatocytes with lipoid inclusions (plasmato-adipohaemocytes) and plasmatocyte with large bulbous cytoplasmic process (cp), first instar larva; C. Uni-nucleated and bi-nucleated plasmatocytes, third instar larva (stained with Leishman's); D. Round and "folded" plasmatocytes, first instar larva; E. Plasmatocyte with cytoplasmic process, also free cytoplasmic remains, first instar larva; F. Round and "folded" plasmatocytes; large plasmatocyte undergoing cell division, first instar larva; G. Plasmatocyte with small cytoplasmic bulbous process and plasmatocyte in late cell division, first instar larva; H. Adipohaemocytes, third instar larva; I. Adipohaemocytes intact at bottom (right), lysing adipohaemocyte above them and lysing granulo-adipohaemocyte (left), third instar larva.

During ecdysis these plasmatocytes accumulate in their cytoplasm large numbers of PAS-positive granules, and apparently lysed tissue: as a result, they appear very similar to granular haemocytes (Fig. 2I). On the other hand, amoeboid forms extend pseudopodia, although the round non-filamentous forms do not do so and appear quiescent.

In sealed coverslip preparations which were allowed to stand at room temperature for 15-20 minutes, the plasmatocytes and plasmato-adipohaemocytes fold at the edges (Fig. 3D, F). They may lyse and form bulbous, cytoplasmic structures (Figs. 2I, 3B, E) or release the nucleus and cytoplasmic remains into the plasma (Fig. 2B, I). In several instances late mitotic division in plasmatocytes was observed in first instar (Fig. 3G) and third instar larvae (Fig. 3C) and a few cases of amiototic division were seen in the first instar larva (Fig. 3F).

Plasmatocytes tend to clump and/or increase in numbers during repeated bleeding in the third instar larvae. Although bulbous processes occur on plasmatocytes following chilling of the third instar larvae for several days, fewer plasmatocytes are affected than those in the first instar larvae.

3. *Adipohaemocytes*

(a) *General Morphology*

These cells are round, ovoid (Fig. 3H, I), fusiform (Fig. 4A-E), amoeboid (Fig. 4F, G) or spiked (Figs. 4H, I, 5A). Early transitional adipohaemocytes have a smooth outline (Figs. 3B, 6A) which becomes increasingly lobed as the cells mature (Figs. 3H, I, 6B, C, D). Fusiform cells are uni- or bi-polar (Fig. 4A-E); degenerating cells have spiky (Fig. 4H, I), long (Figs. 5A, B, 6I) or bulbous (Figs. 6F, G, H) cytoplasmic processes, also granules and partially or completely extruded fat globules (Fig. 7A).

Round adipohaemocytes measure 10.4-20.8 u in diameter with nuclei 7.2-15.3 u in diameter. Their average nuclear cytoplasmic ratio is 0.6 (Table 1).

In fresh haemolymph, the cytoplasm appears greyish-green with variable numbers of spherical yellowish-green lipoid inclusion bodies of various sizes; the inclusion bodies contain tiny granules which display Brownian movement. The nucleus may be excentric and partially surrounded by horse-shoe shaped lipoid inclusion bodies, or centric and completely occluded by them. The nucleus is large and round, with numerous punctate granules and a nucleolus.

In wet preparations of haemolymph from the third instar larvae stained with 2% lacto-aceto-orcein the nucleus appears pinky red and the chromatin granules stain deep red either peripherally or scattered throughout the nucleus.

In freshly prepared smears stained with Leishman's, the cytoplasm appears blue and the nucleus pink or purple; the lipoid inclusions do not stain. Brownish-black granules may be observed within the cytoplasm and lipoid inclusions. The granules are pear-shaped with their broad ends toward the periphery of the cell and the narrower darker portions toward the nucleus. Nuclei which are located centrally or partially occluded by the cytoplasmic inclusions stain purple, while the unoccluded excentric nuclei stain pink. Large and small chromatin granules are seen within the nucleus. Bi-nucleate forms are also observed.

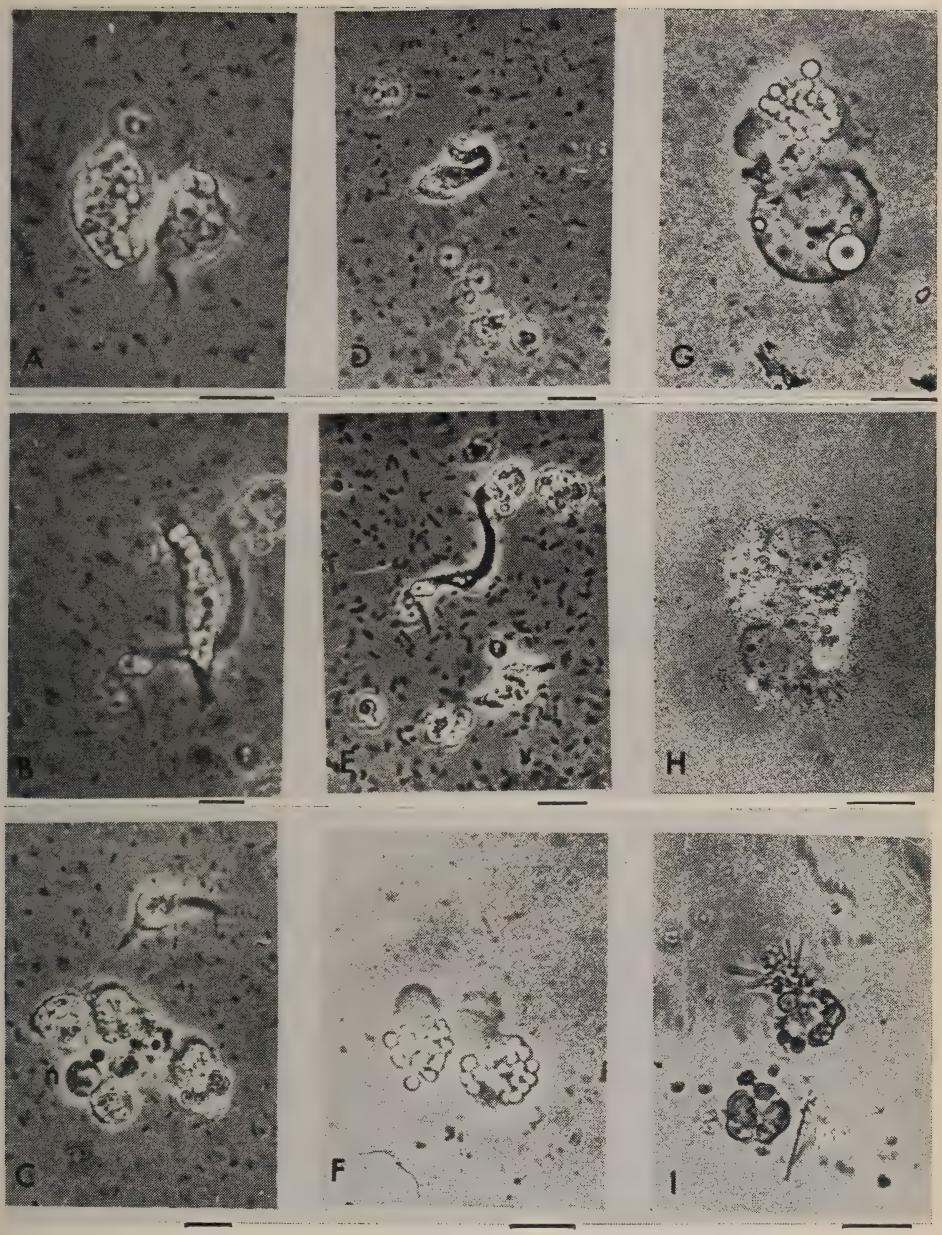

FIGURE 4. Adipohaemocytes from third instar larva and prepupa of *Hypoderma*, showing:— A. Lysing adipohaemocyte and bacilli, prepupa; B. Elongated adipohaemocyte, prepupa; C. Bi-polar adipohaemocyte, lysing adipohaemocytes and partially released nucleus (n), prepupa; D. Irregularly shaped adipohaemocyte, fat globules and bacilli, prepupa; E. Adipohaemocyte intact (top right), lysing adipohaemocyte with long cytoplasmic strand, fusiform adipohaemocyte, fat globules and bacilli, prepupa; F. Amoeboid adipohaemocytes from four-week-old *in vitro* preparation, third instar larva; G. Lysing adipohaemocyte with prominent nucleus and main cytoplasmic area almost free of fat globules, four-week-old *in vitro* preparation, third instar larva; H. Adipohaemocyte with discrete fat globules, clear cytoplasmic areas and spikes, four-week-old *in vitro* preparation, third instar larva; I. Adipohaemocyte with spikes, another with coalesced fat inclusions and free cytoplasmic remains, four-week-old *in vitro* preparation, third instar larva.

(b) *Occurrence*

Round or ovoid forms were observed in all stages of development, but many in the third instar (Table 1). Few adipohaemocytes occurred in the pupal and adult stages. Mainly transitional forms occurred in the first instar larvae (Fig. 6A). The amoeboid and spiky forms were obtained from the third instar larvae about 24 hours after the formation of the prepupa (Figs. 5A, B, 6I), and from four-week-old undiluted haemolymph in sealed coverslip preparations (Figs. 4F, H, I, 6G, H). Fusiform cells were seen in a 12-20-hour-old prepupa (Fig. 4A-E).

(c) *Behaviour*

(i) *Fresh preparations*

The cells are motile and phagocytic, pushing out pseudopodia and filipodia. The filipodia have adhesive ends to which micro-organisms etc. become attached and are then drawn back into the cytoplasm. The filipodia also display searching and probing motions like the filipodia of plastmatocytes.

Haemolymph from a third instar (white) larva contains adipohaemocytes, some of which put out bulbous cytoplasmic processes 5 to 10 minutes after bleeding (see Fig. 6B-F). These processes are bluish or clear and contain either granular substances, fat globules or both thus resembling plasmatocytes, large transitional adipohaemocytes or granulo-adipohaemocytes respectively. The production of cytoplasmic processes can also be seen in many adipohaemocytes in haemolymph taken from third instar larvae which were chilled for several days or repeatedly bled (Fig. 6E, F). Chilling and repeated bleeding also caused the adipohaemocytes to clump or release clumps of cytoplasmic structures into the plasma. On several occasions the nucleus was expelled and existed freely or with cytoplasmic remains attached (Figs. 4C, 5A, 7B). On a few occasions the cytoplasmic remains and nucleus also became attached to the periphery of a fat globule (Fig. 7C) and displayed actively phagocytic and motile behaviour characteristic of granular haemocytes.

Two days prior to the formation of the prepupae, numerous adipohaemocytes were seen, often in clumps. One day before the prepual stage most of the adipohaemocytes had spike-like processes and cloudy areas (Fig. 5A). Other cells had enlarged and had lipoid inclusions scattered through their cytoplasm (Figs. 5A, B, 6I). Some degenerate adipohaemocytes were observed with free nuclei and cytoplasmic remains which sometimes surrounded large lipoid inclusions (Figs. 5A, B, 7B). Degeneration continued into the prepual stage, but some elongated cytoplasmic structures and enlarged cells were still present; there were also increases in the numbers of fusiform cells (Figs. 4A-E) and enucleated cells (Figs. 5A, 7B).

(ii) *Four-week-old haemolymph*

The cells enlarge and the lipoid inclusions scatter throughout the cytoplasm (Figs. 4F, G, H, 6G, H). They may burst through the cell membrane while remaining attached to it (Fig. 7A) or break away completely and scatter through the plasma. Most of the lipoid inclusions disappear from the adipohaemocyte cells which occasionally resemble plasmatocytes (Fig. 7D). The lipoid bodies may be round, 'pear-shaped' or amorphus depending on the period for which the haemolymph is stored. Some cells have bulbous structures or pseudopodia (Fig. 4F, G).

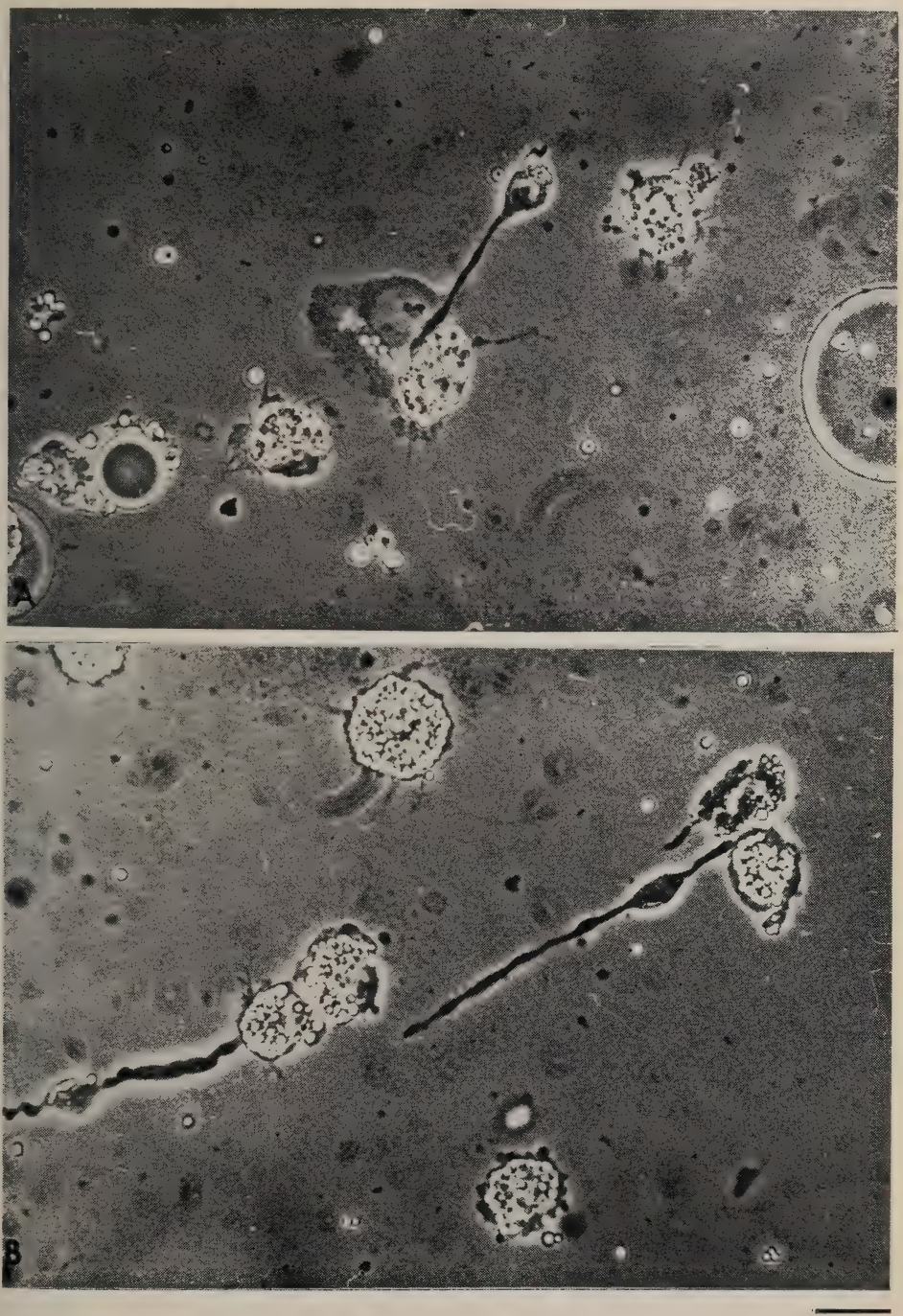

FIGURE 5. Adipohaemocytes from third instar larva of *Hypoderma,* 1 day prior to prepupal formation, showing:—A. Lysing adipohaemocytes with spikes, long cytoplasmic process, ejected nucleus and cytoplasm, also free fat globules; B. Lysing adipohaemocytes, two with long cytoplasmic processes, also nucleus and cytoplasm (top right).

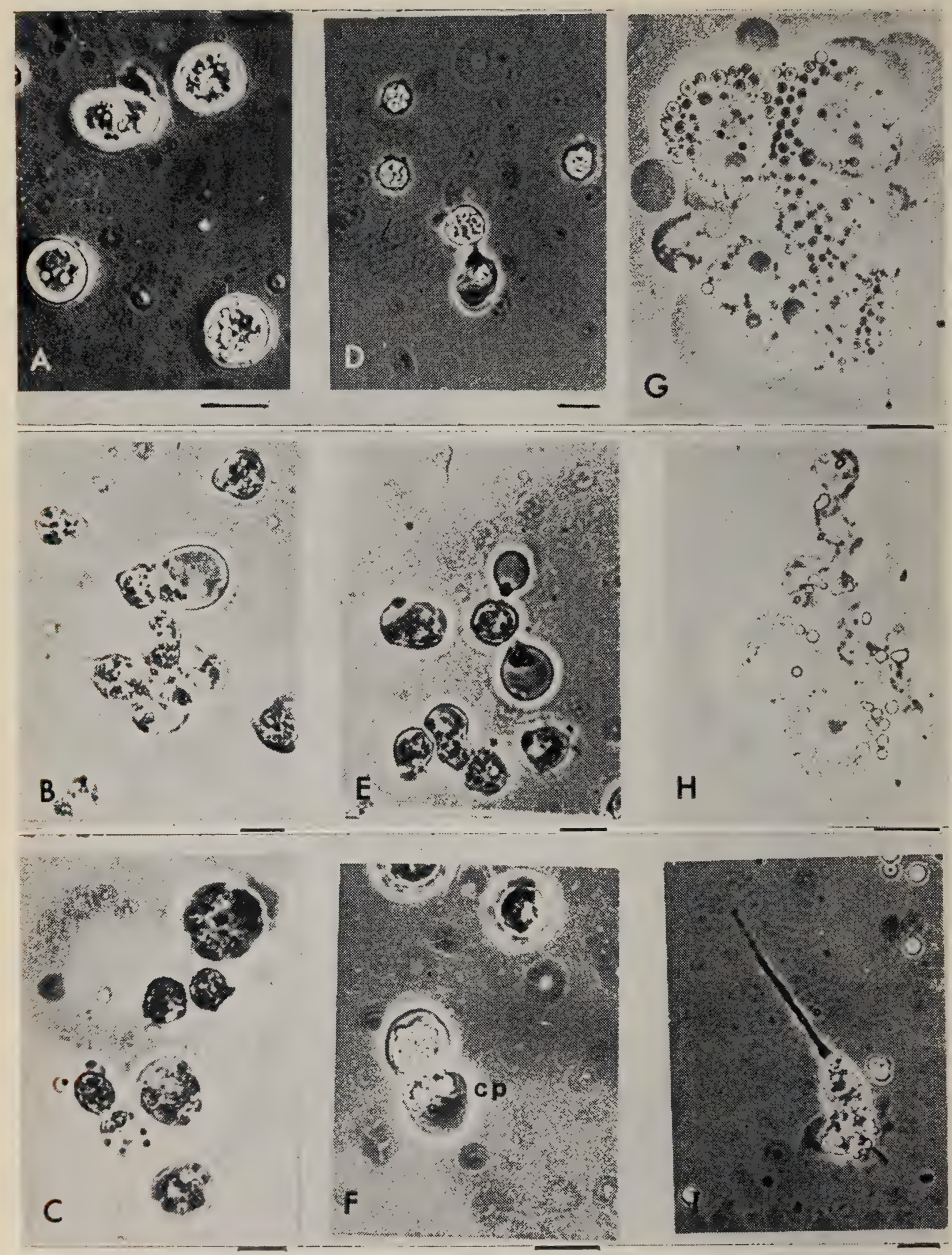

FIGURE 6. Adipohaemocytes from larva of *Hypoderma*, showing:—A. Plasmato-adipohaemocytes, first instar larva; B. Four immature adipohaemocytes (at corners), immature adipohaemocyte with bulbous cytoplasmic process and granulo-adipohaemocyte breaking down into three parts, white third instar larva; C. Two small immature adipohaemocytes, immature adipohaemocyte with bulbous cytoplasmic process and three large granulo-adipohaemocytes, white third instar larva; D. Three immature adipohaemocytes and immature adipohaemocyte with cytoplasmic process, white third instar larva; E. Large granulo-adipohaemocyte, four small immature adipohaemocytes (bottom) and lysing immature adipohaemocyte with two bulbous cytoplasmic processes, third instar larva; F. Lysing adipohaemocyte with large bulbous

cytoplasmic process (cp), third instar larva; G. Adipohaemocytes with discrete fat inclusion bodies, apparent nucleated structures, vacuolated and non-vacuolated cytoplasmic processes from wour-week-old *in vitro* preparation, third instar larva; H. Adipohaemocytes with discrete fat inclusion bodies and long cytoplasmic process from four-week-old *in vitro* preparation, third instar larva; I. Lysing adipohaemocytes with long cytoplasmic process, third instar larva 1 day prior to formation of prepupa.

Others may lyse or fuse with neighbouring cells (Fig. 6G, H). In these conditions the nucleus and cytoplasm of the adipohaemocytes appear brownish-yellow. Still other cells may have yellowish cytoplasm and spikes (Fig. 4H, I) which may break away from the cell, forming plastids (Fig. 4I).

4. *Granular Haemocytes*

(a) *General Morphology*

These cells are round (Fig. 7E-H), ovoid (Fig. 2I) or amoeboid (Fig. 7I). The round forms measure 6.5 - 26.0 u in diameter with nuclei 3.9 u. The average nuclear cytoplasmic ratio is 0.3 (Table 1).

In fresh undiluted coverslip preparations, the cytoplasm is greyish-green with bluish and reddish granules either alone (Fig. 7E, F), or in association with fat globules (Figs. 7G, H, I). The cytoplasmic inclusions often occlude the nucleus (Fig. 7G, H, I) which may be round (Fig. 7E, H) or oval with chromatin granules. Uninucleate and bi-nucleate granular haemocytes occur in fresh haemolymph (more readily observed in preparations stained with 2% lacto-aceto-orcein and Leishman's).

In freshly made thick and thin smears stained with Leishman's, the nucleus appears eosinophilic with basophilic cytoplasm.

(b) *Occurrence*

Granular haemocytes occur in all stages of development but their numbers vary according to the physiological status of the organism.

(c) *Behaviour*

The granular haemocytes are motile and phagocytic. They may be round or amoeboid. Amoeboid forms have pseudopodia which engulf granules and fat globules; round forms push out cytoplasmic processes with adhesive disc-like ends. Large granular haemocytes (Fig. 7F) may burst, liberating granules.

5. *Granulo-adipohaemocytes*

(a) *General Morphology*

These cells are round or ovoid (Fig. 8 A-C, F-I), measuring 18.0-34.9 u in diameter with nuclei 8-13 u and a nuclear cytoplasmic ratio of 0.4 (Table 1).

In fresh sealed coverslip preparations of the adult the cytoplasm first appears hyaline with an indistinct nucleus. Later bluish and reddish granules and/or fat globules gradually increase in numbers. The granules and globules become scattered later throughout the cytoplasm or located at the cell periphery; they may also

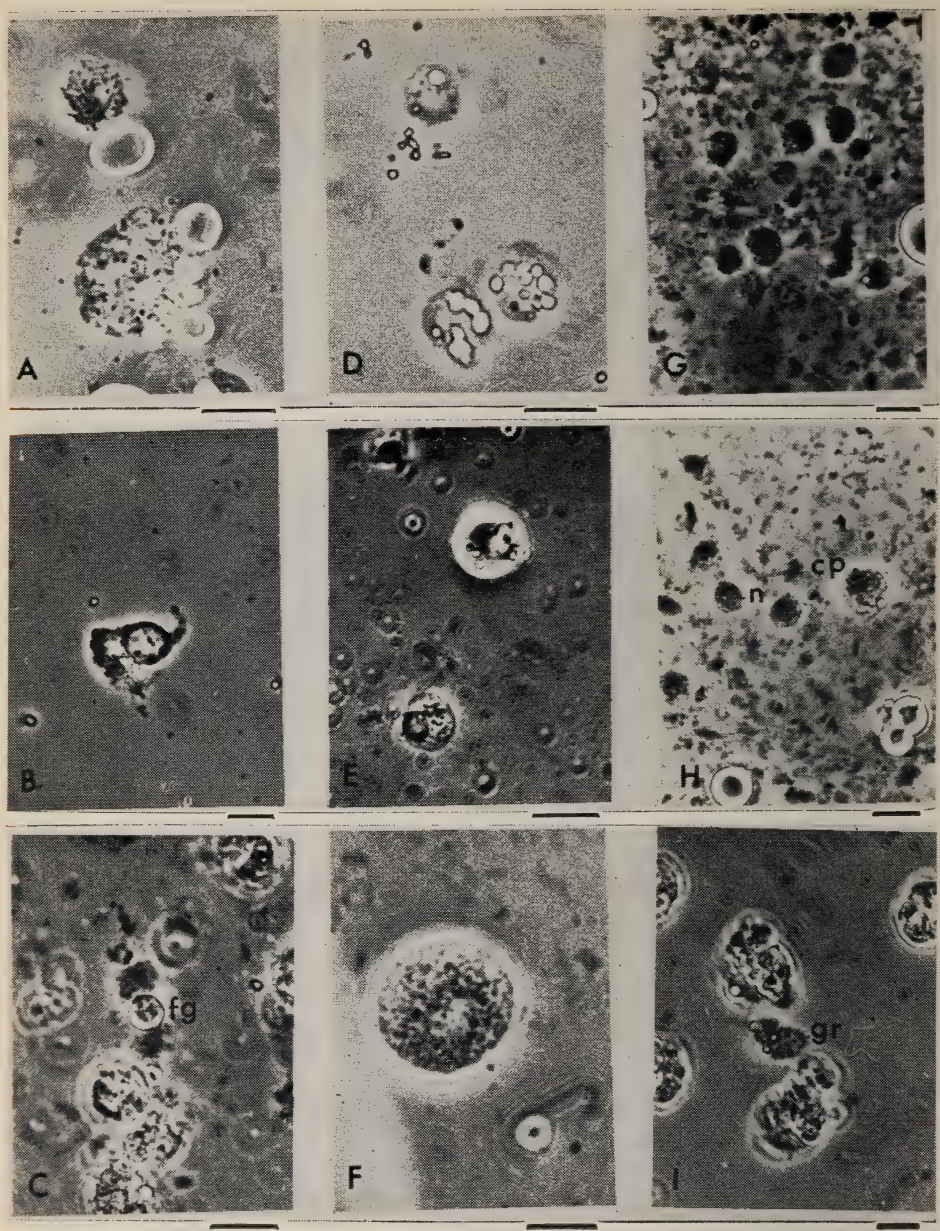

FIGURE 7. Haemocytes of *Hypoderma* larva, showing:—A. Adipohaemocytes with increased granularity also liberation of fat globules from four-week old *in vitro* preparation, third instar larva; B. Nuclear and cytoplasmic remains of lysed adipohaemocyte, third instar larva 1 day prior to formation of prepupa; C. Adipohaemocyte (middle) with cytoplasmic remains attached to fat globule (fg) and other adipohaemocytes, four-week-old *in vitro* preparation, third instar larva; D. Three adipohaemocytes with fewer than usual lipoid inclusions (top one resembles plasmatocyte), four-week-old *in vitro* preparation, third instar larva; E. Granular haemocyte (bottom) and plasmato-adipohaemocyte (above), first instar larva; F. Large granular haemocyte, third instar larva; G. Granular haemocytes and bacteria, four-week-old *in vitro* preparation, third instar larva; H. Granular haemocytes, bacteria and lysing adipohaemocyte with fat globule(s) in four-week-old *in vitro* preparation, third instar larva; I. Lysing adipohaemocytes and a single granular haemocyte (gr), four-week-old *in vitro* preparation, third instar larva.

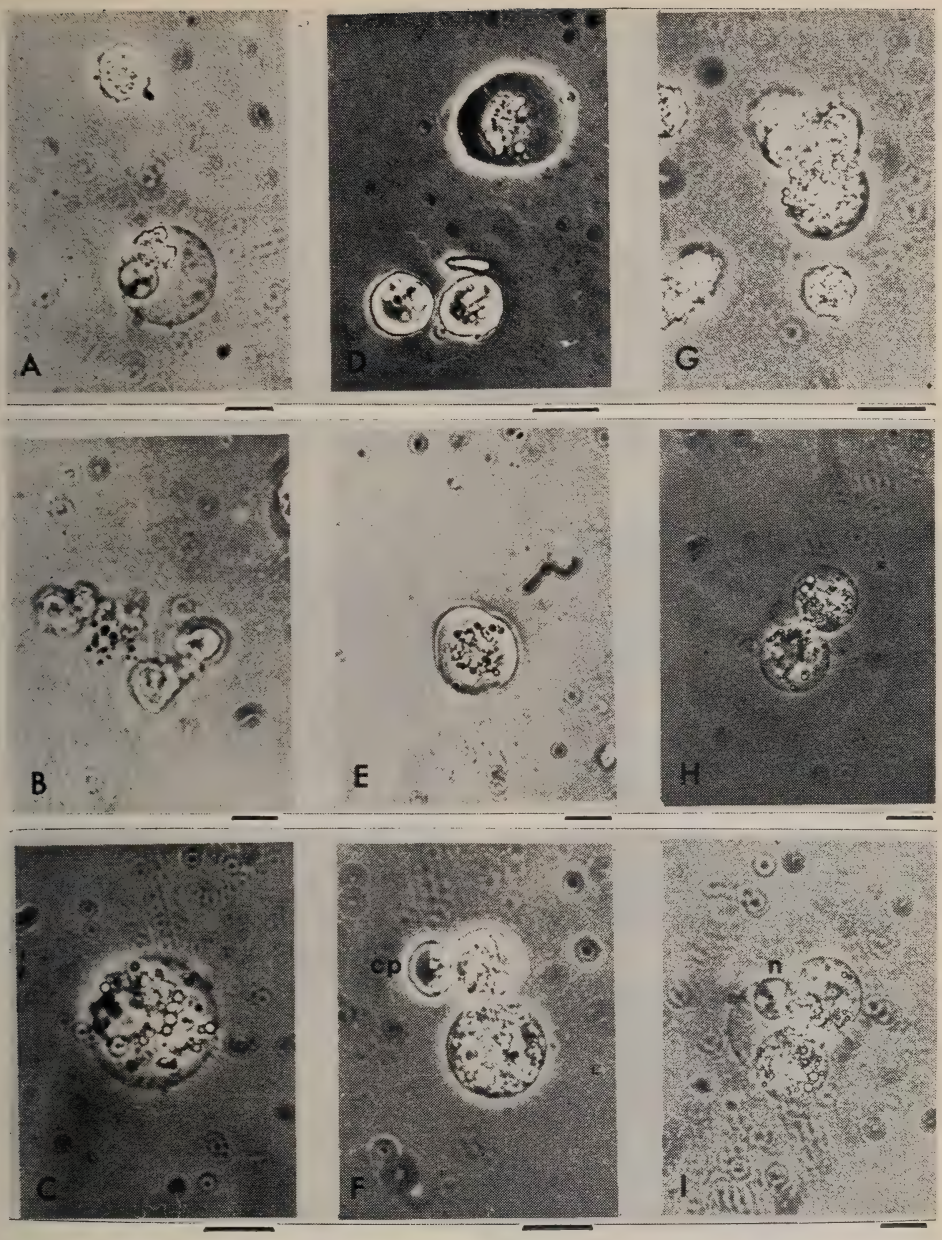

FIGURE 8. Adipohaemocytes from *Hypoderma,* showing:—A. Large granulo-adipohaemocyte and small immature adipohaemocyte, white third instar larva; B. Granulo-adipohaemocyte with granules, and lipoid inclusion also lysing immature adipohaemocytes, white third instar larva; C. Large granulo-adipohaemocyte with distinct nucleus, granules and lipoid inclusion bodies, third instar larva; D. Dense cytoplasmic structure from lysing granulo-adipohaemocyte (top) and two plasmato-adipohaemocytes, first instar larva; E. Dense cytoplasmic structure from lysing granulo-adipohaemocyte with granules and lipoid inclusion bodies, third instar larva; F. Granulo-adipohaemocyte (middle) with numerous lipoid inclusion bodies and few granules; lysing adipohaemocyte with bulbous cytoplasmic process (cp), white third instar larva; G. Lysing granulo-adipohaemocyte (middle) and three adipohaemocytes, third instar larva; H. Two lysing granulo-adipohaemocytes with two small cytoplasmic bulbous processes, white third instar larva (and see I); I. Later stage, one cytoplasmic bulbous process enlarged and nucleus (n) being released from cell.

occur around the nucleus and hide it from view. These inclusions make the cytoplasm appear milky (Fig. 8B) or grey-green with a yellow colour at the periphery. The nucleus is large, round, excentric and usually peripheral (Fig. 8A, C). Chromatin granules are obvious, especially when stained with 2% lacto-aceto-orcein or Leishman's.

(b) *Occurrence*

Granulo-adipohaemocytes occur in all stages of development but are most common in the third instar larvae.

(c) *Behaviour*

These cells are phagocytic and move by means of filipodia and pseudopodia. Probing was commonly seen and the adhesive quality of the filipodia was also observed, indicating phagocytic potential. Numerous granules and globules accu-

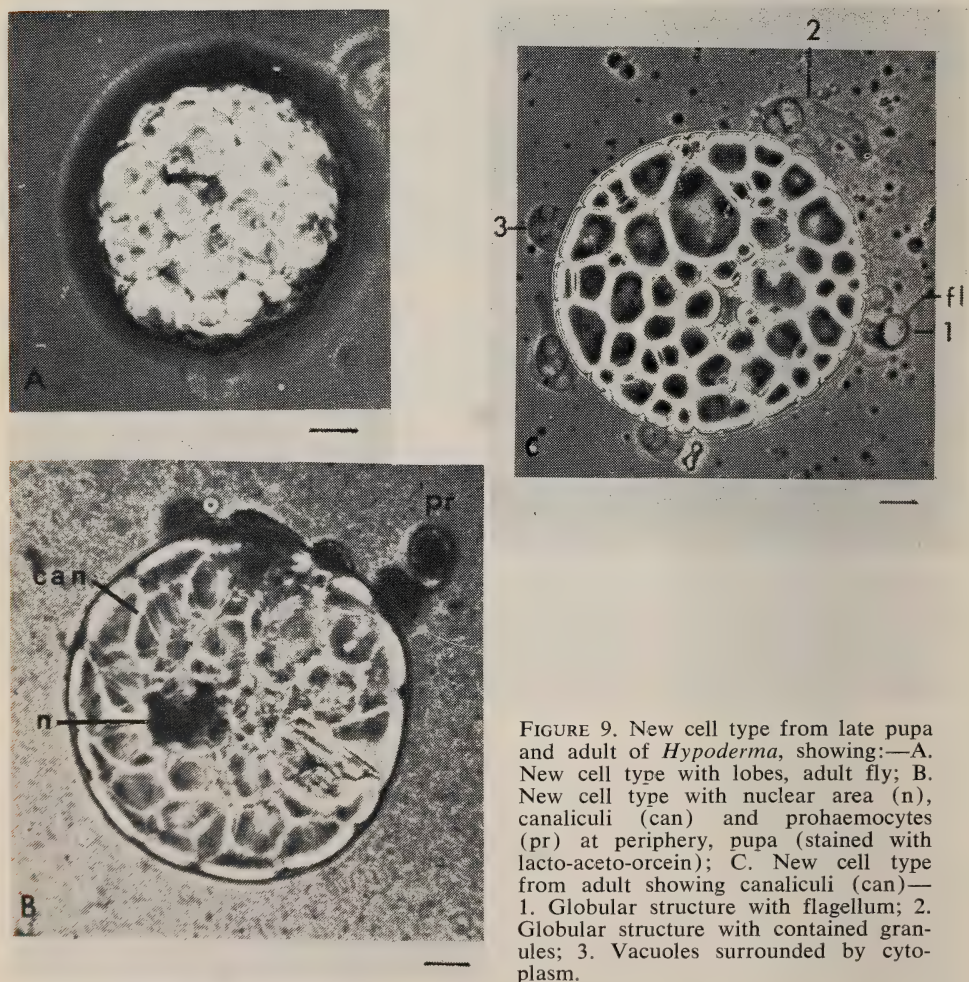

FIGURE 9. New cell type from late pupa and adult of *Hypoderma*, showing:—A. New cell type with lobes, adult fly; B. New cell type with nuclear area (n), canaliculi (can) and prohaemocytes (pr) at periphery, pupa (stained with lacto-aceto-orcein); C. New cell type from adult showing canaliculi (can)—1. Globular structure with flagellum; 2. Globular structure with contained granules; 3. Vacuoles surrounded by cytoplasm.

mulate within the cells (Fig. 8 A-C, F-I) which disintegrate easily liberating most of the cytoplasmic contents into the plasma (Figs. 6B, 8D, E, G, I) with the rest remaining around the nucleus. Large bead-like hyaline structures may remain attached by cytoplasmic strands to the nucleus and the remains of the cytoplasm. Large bluish prominences may extend from the cytoplasm when preparations are kept sealed (Figs. 8H, I) for several hours or when samples of haemolymph from the first and third instar larvae are mixed together. In the latter case the cells soon lyse.

Discussions

Various systems for the classification of insect haemocytes have been described (Wigglesworth, 1959; Jones, 1962). The different systems have resulted from the varying techniques used in staining the cells, the diversity of insect species studied and the morphology of the cells with no regard to their polymorphism, transitional stages, lytic processes and any associated artifacts.

Jones (1962) indicated that in the Diptera there are generally three main types of haemocytes: prohaemocytes, plasmatocytes and granular haemocytes. In addition there are spherules and adipohaemocytes. These cells were classified on the basis of their morphology and function. Crossley (1964) described seven types of haemocytes in *Calliphora erythrocephala* (Meig.) using letters (A, B, C, D, E, F, Z) rather than names. These cells were observed with phase contrast microscopy and classified on the basis of morphology, histochemistry and function. In *Hypoderma* there are six types — prohaemocytes, plasmatocytes, granular haemocytes, adiphohaemocytes, granulo-adipohaemocytes and a new type of haemocyte. These cells are classified on the basis of their morphology, occurrence, histochemistry and physiology.

The *prohaemocytes* in *Hypoderma* are small (2.5-11.6 u), round or ovoid, compact cells with an indistinct separation between nucleus and cytoplasm. They appear greyish green with phase microscopy. They give rise to other cells and are therefore analogous to the proleucocytes of *Calliphora* (Akesson, 1954) and Simuliidae (Rubtsov, 1959), prohaemocytes of *Sarcophaga* (Jones, 1956, 1962, 1967; Whitten, 1964), macronucleocytes of Simuliidae, (Rubtsov, 1959) and "Type Z" cells of *Calliphora* (Crossley, 1964).

Plasmatocytes, in the present study, measure 2.5-28.8 u in diameter. They are polymorphic (round or oval) with large amounts of cytoplasm and a small nucleus. The filipodia observed on plasmatocytes correspond to those in *Sarcophaga* (Jones, 1956), to the podocytes in *Drosophila* (Ritzki, 1953, 1957a), the "Type A" cell in *Calliphora* (Crossley, 1964) and the oval plasmatocytes in the prepupae of *Sarcophaga* (Whitten, 1964). Fusiform types of plasmatocytes in *Hypoderma* contain uni- and bi-polar filaments. Similar cells with bipolar filaments were also observed in *Sarcophaga* by Jones (1956, 1962) and Whitten (1954): they also appear to be analogous to the nematocytes of Ritzki (1953), Types 5 and 7 of Akesson (1954), spindle-shaped cells of Rubtsov (1959) and "Types D and E" cells of Crossley (1964). Round and oval plasmatocytes without filaments were also seen; these resemble those described by Jones (1956, 1962), Ritzki (1957a), Whitten (1964); the Type 2 cells of Rooseboom (1937) and Akesson (1954) and "Type C" cells of Crossley (1964). Other workers never observed amoeboid plasmatocytes to send out blunt pseudopodia or to become truly spike-like. These forms may be regarded as degenerative phases because they were observed mainly in a single four-week-old undiluted sealed coverslip preparation.

One common feature of granular haemocytes in insects is their phagocytic activity, as a result of which numerous fragments or granules, and sometimes fat globules, are taken into the cytoplasm. In *Hypoderma* granular haemocytes were observed in the larval and pupal stages mainly during moulting or bacterial invasion. Fat globules occur frequently in the granular haemocytes during pre-pupal development. This is apparently due to the phagocytic activity of the cells in ingesting fat globules which have been liberated into the haemolymph from lysed cells which contained fat. Accumulations of masses of fat globules during the larval stages, as seen by Crossley (1964) in the transitional stages of the "Type A" cells to granular haemocytes in *Calliphora,* are rarely encountered among Diptera and were not observed in *Hypoderma.* These cells are nevertheless analogous to the Type 3 cell of Rooseboom (1937) and Akesson (1954), the phagocytic cell of Dennell (1947), and the granular haemocyte of Jones (1956), Whitten (1964) and Crossley, 1964, (Fig. 5h and i, p. 386). Cells containing 3 or more nuclei were seen in *Sarcophaga* by Whitten (1964): these were not seen in *Hypoderma,* which has only bi-nucleate forms (easily recognizable after staining with 2% lacto-aceto-orcein or Leishman's).

Plasmato-adipohaemocytes have characteristics in common with both plasmatocytes and adipohaemocytes. Morphologically, they are closer to plasmatocytes, but differ in having lipids, which can also be demonstrated in adipohaemocytes. These cells are comparable to the young adipohaemocytes of Rubtsov (1959) and Crossley 1964, (Fig. 3c, p. 381).

Granulo-adipohaemocytes are cells containing both granules and lipoid inclusion bodies in an opalescent cytoplasm. They are equivalent to the lamellocytes of Rizki (1957a) and Types 6 and 8 cells of Akesson (1954). Some of these cells may also lyse and then produce long cytoplasmic strands or bulbous processes: this apparently led Jones (1956) to regard them as degenerated stages of spherule cells and he called them giant spherules. However, these cells seem to represent a distinct form of haemocyte in *Sarcophaga* (the hyaline cells: Whitten, 1964) and in all stages of *Hypoderma.* The "Type B" cell of *Calliphora* (Crossley, 1964) also has many similarities to the granulo-adipohaemocytes of *Hypoderma,* including the ratio of diameter of the nucleus to that of the cell.

Adipohaemocytes in *Hypoderma* as in *Drosophila* (Whitten, 1964) are morula-like cells which contain fat inclusions and other materials. The nucleus is large but becomes occluded by ovoid and spherical lipoid inclusions in the later stages of larval development. Probably due to the large number of spherical inclusions the cells have been termed spherules by Akesson (1954), Jones (1956, 1967), Crossley (1964) and Whitten (1964). These cells are also analogous to the granular leucocytes of Dennell (1947), spheroidocytes of Rizki (1953), adipocytes of Rubtsov (1959) and "Type F" cell (see also Fig. 58, p. 386 of Crossley, 1964).

Although "Type F" cells in *Calliphora* (Crossley, 1964) and adipohaemocytes in *Hypoderma* have filipodia and display phagocytic activities, no broadly based pseudopodia are involved as indicated by Akesson (1954) and Whitten (1964). However, pseudopodia-like extensions are seen in the adipohaemocytes in *Hypoderma* one day before formation of the prepupa and in the prepupa and were also seen in a 28-day-old undiluted coverslip preparation of haemolymph taken from a third instar larva. These adipohaemocytes are not phagocytic in *Hypoderma* but have been observed to lyse prior to melanization and hardening of the larval cuticle. Since Akesson (1954) and Whitten (1964) observed pseudopodia-like

extensions of the spherule cells in the pupal stage when the tissues were lysing, it seems likely that they regarded the extension of the cell as truly phagocytic rather than as part of a lytic process.

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A COMPARISON OF EUROPEAN CORN BORER, *OSTRINIA NUBILALIS* (HUBNER), MOTH FLIGHT TO LIGHT TRAPS IN SOUTHWESTERN ONTARIO AND THE RELATIONSHIP TO BORER INFESTATION

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Abstract

The flight over a 17-year period of European corn borer, *Ostrinia nubilalis* (Hübner), moths to two different light traps situated nearly 60 miles apart, is discussed. The relationship of moth flight to infestation in field corn is also considered. Consistently higher captures, with minor exceptions, were made at

[1] Stationed at Chatham, Ontario

the more southern (Harrow) trap, which also had higher percentages of second-generation moths. Sex ratio was consistently oriented to the female at Harrow and toward the male at Chatham. A high moth flight does not necessarily mean a high field infestation, but a relationship seemed to exist between a small flight and a low field infestation.

* * * * * *

In a previous paper (Wressell, 1953) I indicated that, during the period 1932 to 1951, the European corn borer, *Ostrinia nubilalis* (Hübner), changed from a univoltine to a multivoltine insect in southwestern Ontario. This information was obtained by analysing the numbers of corn borer moths captured at a light trap operated at Chatham, Ontario. In the earlier paper I demonstrated that, from 1932 to 1938, the percentage of second-generation moths in the total flight ranged from zero to only 6%. In 1939, however, there was a sudden upsurge of multivoltinism when 13% of the catch was taken in the late summer. There was a drop-off in 1940 and 1941, but from 1942 on, the numbers of second-generation moths captured at the trap steadily increased and, by 1951, the figure was 71%.

The present paper carries the study from 1952 to 1968. The data presented substantiates the conclusions given in the earlier paper, and clearly demonstrates that multivoltinism is dominant in southwestern Ontario. A comparison is also made of the flight pattern of two different light traps—one located at Chatham and the other at Harrow, Ontario, where a light trap has been operated since 1952. The relationship of light trap catches to field infestation is also discussed.

Materials and Methods

The light traps used in this study were of the modified DeGryse type as described in my earlier publication *(loc.cit.)*. It was considered desirable to use this particular type of trap so that comparisons might be made with earlier seasons. The capture of large numbers of moths, as described by Hollingsworth (1968), Taylor and Deay (1950), and Ficht and Heinton (1940), was not a desideratum in the present study. So the use of an UV type of trap was unnecessary. According to Frost (1952), traps of the type used in this work have proved quite successful in the United States. The source of light was a 100-watt incandescent, frosted bulb placed about eight feet from ground level. Hydrocyanic gas, in the form of calcium cyanide, was used as the killing agent. The Chatham trap had been in the same location, on a farm three miles south of the city, from 1931 to 1968, inclusive. Harrow, where the second trap was located, is some 60 miles southwest of Chatham but, in terms of actual latitude, is less than half of one degree to the south. The results for 1959 are not considered for Harrow in this paper. Collections made in that year were attacked by moulds before identifications could be made. Also, for Harrow, the records for 1952, 1953, and 1955 are incomplete but, since certain results are pertinent to the discussion, the incomplete figures are presented in Table II.

Ordinarily, collections were made every second day and the moths were recorded by numbers and by sex shortly afterwards. In order to offset an overlap between generations in July, it was thought desirable to allow a 10-day interval, when no moths were captured, to be the buffer period between the generations. It is conceivable that some moths taken after this 10-day interval might belong to the first generation, but the number was considered insignificant. The peak date of flight is actually the date when the greatest number of moths were captured over a given five-day period.

TABLE I. Flight of European corn borer, *Ostrinia nubilalis* (Hubner) to light trap, Chatham, Ontario, 1952 - 1968, inclusive.

Year	First date of flight	Last date of flight	Peak date of flight	Moths captured	Per cent female moths	Per cent second generation	Flight period in days
1952	June 8	Sept. 2	Aug. 18	239	47	72.5	86
1953	June 8	Sept. 3	Aug. 29	268	28.5	56.5	87
1954	June 11	Sept. 4	Aug. 24	122	39	43	85
1955	June 7	Oct. 1	Aug. 16	709	30	81.5	116
1956	June 13	Sept. 14	Aug. 29	1172	35	49	93
1957	June 13	Sept. 19	Aug. 30	577	43	72	98
1958	June 10	Oct. 10	Sept. 4	225	40	62	122
1959	June 10	Sept. 15	Aug. 15	149	44	78	97
1960	June 14	Sept. 9	Aug. 29	437	41	67	87
1961	June 14	Sept. 12	Aug. 28	319	31	83	90
1962	June 6	Sept. 18	Aug. 13	112	35	70	104
1963	June 6	Sept. 15	Aug. 21	191	42	83	101
1964	June 18	Sept. 18	Aug. 22	226	42	59	92
1965	June 7	Sept. 20	No peak	69	31	69	105
1966	June 18	Sept. 14	Aug. 15	196	27	79	88
1967	June 13	Sept. 17	Aug. 27	239	48	80	96
1968	June 24	Sept. 23	No peak	61	46	90	91
							Average flight period 97 days

TABLE II. Flight of European corn borer, *Ostrinia nubilalis* (Hubner) to light trap, Harrow, Ontario, 1952 - 1968, inclusive.

Year	First date of flight	Last date of flight	Peak date of flight	Moths captured	Per cent female moths	Per cent second generation	Flight period in days
1952	June 23	Aug. 28*	Aug. 18	548	53	97	—
1953	June 11	Aug. 20*	June 18	175	48	33	—
1954	June 21	Spet. 28	Aug. 29	270	58	87	99
1955	June 3	Aug. 19*	Aug. 10	569	49	64	—
1956	June 13	Oct. 17	Aug. 14	920	54	60	126
1957	June 12	Sept. 23	Sept. 5	730	51	83	103
1958	June 16	Sept. 25	Sept. 8	337	51	90	101
1959*				No Record			
1960	June 14	Sept. 30	Aug. 29	1104	51	95	108
1961	June 9	Sept. 25	Aug. 24	470	60	92	108
1962	June 5	Sept. 17	Aug. 13	926	61	95	104
1963	June 7	Sept. 16	Aug. 29	155	69	83	101
1964	June 8	Sept. 8	Aug. 31	722	57	91	92
1965	June 5	Sept. 20	Aug. 21	474	54	94	107
1966	June 15	Sept. 22	Aug. 15	633	54	92	99
1967	June 13	Sept. 25	Aug. 24	675	50	94	104
1968	June 5	Sept. 29	Sept. 14	697	53	98	116
							Average flight period 105 days

*Incomplete season

*1959 — No Record

Discussion of Flight to Light Traps

Tables I and II show many similarities between the two light trap sites and some important differences. (1) There is great variation in the initial date of flight at each site; this can vary by as much as three weeks. (2) There is even greater variation in the date of termination of flight, at each site, which can vary by more than five weeks, as in 1956. (3) There is agreement that the peak of moth flight occurs in late summer or early fall, usually in late August. This would indicate that the second generation now predominates in the total population. This is borne out, of course, in Column 7, where the actual percentages of second-generation moths captured are given. (4) The percentage of moths belonging to the second generation is greater in Essex County than in Kent. (6) The majority of moths taken at Chatham are males, while at Harrow the ratio more nearly approaches 50:50 or leans toward a greater percentage of female moths. (7) Yearly flight fluctuations are greater at Chatham than at Harrow.

Light Traps and Field Infestation

From 1946 to 1963 a survey was made, each fall, of European corn borer infestation in field corn. The five southwestern counties were surveyed, but in Kent and Essex the study was more thorough since corn acreage was greatest here. In both Kent and Essex, 25 to 30 fields were selected randomly and 100 plants were examined in each field, in lots of 10, at random, for infestation; leaf feeding, borer cavities, and stalk breakage were all considered. In addition, the borer population was found by dissecting 10 infested plants in each field and counting the number of borers or pupae present. If the field infestation was less than 10%, all the infested plants found in the sample were dissected. Thus, if a field showed 50% infested plants and two borers per stalk were found in the dissected sample, by extrapolation, the average number of borers per 100 plants would be 100.

A 12-year selection, shown in Table III, gives a summary of the field infestation data. The borer population is in parentheses.

It is quite apparent that during this 12-year period severe infestation was present only in Essex County in 1955. Damage was moderately severe in Essex in 1953 and 1956. Severe damage was absent in Kent County except in isolated fields, and moderately severe damage occurred only in 1955 and 1956. In both counties, damage was light to moderate during most of the years under discussion.

Examination of moth flight data shows that 1955 and 1956 were heavy flight years at both Harrow and Chatham. These were years when field infestation was severe or moderately severe. At first glance it would appear that a strong correlation exists between moth flight and field damage. But this is not always the case. In contrast, 1960 was a very heavy flight year at Harrow, when 1104 moths were captured—the greatest number ever recorded at this trap. But field infestation in grain corn was relatively low, only 22%. In Kent, moth flight was relatively heavy in 1960 but field infestation stood at only 13%. On the other hand, it is noteworthy that 95% of the Harrow moths belonged to the second generation and late processing corn was severely damaged. But in Kent processing corn suffered little damage.

Working with first-generation borers only, Stirrett (1938) stated "The seasonal abundance of the borer cannot be judged by the attraction of adults to light traps." Earlier, Cook (1928) came to the conclusion that moths (in this case Family Noctuidae) do not come to light in proportion to their abundance as species

TABLE III. Percentage infestation and borer population by European corn borer, *Ostrinia nubilalis* (Hubner), 1952 - 1963, inclusive.

County	Year											
	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Essex	22(17)	47(109)	12(8)	75(384)	51(184)	27(46)	17(23)	26(50)	22(28)	17(22)	23(40)	8(3)
Kent	15(14)	18(32)	8(5)	40(148)	35(63)	27(27)	17(18)	20(28)	13(7)	6(5)	6(8)	2(1)

in any given year. In his review of insect pests of rice, Pathak (1968) cites Japanese workers attempting to control stem borer moths, mainly the Asiatic rice borer, *Chilo suppressalis* (Walker), by means of light traps. He points out that even when 80 light traps per hectare were used, only 50% of the moth population could be attracted. He also stated that "Light traps are presently (1967) used for studying population fluctuations." Brindley and Dicke (1963), commenting on the use of light traps for corn borer control, state "Light traps, of various types and with different light sources, to attract moths, have commonly been used to obtain information on seasonal abundance."

The highest infestation year, during the period when an annual survey was made, was in 1949. For Essex, the average percentage infestation in 28 fields examined was 88; in Kent, the figure was 72% in 28 fields. In Essex, 17 fields had over 90% stalk and ear damage, of which four fields showed 100% damage. In one of the completely damaged fields there was an average population of 14 borers per plant (10 plants in each field were dissected). In Kent, seven fields out of 25 examined showed over 90% stalk and ear damage; of these, two had 100% infested plants. In Kent, the highest borer population had an average of 9.5 borers per plant. No light trap was in operation at Harrow in 1949 but, at Chatham, 435 moths were captured. During four other years, at Chatham, the number of moths captured was as high as, or higher than, the number taken in 1949. However, as shown in Table IV, the field infestation was much lower.

TABLE IV. A comparison of corn borer moths captured at a light trap, and field infestation in corn, Chatham, Ontario.

Year	1949	1955	1956	1957	1960
Light trap captures	435	709	1172	577	437
Field infestation	72%	40%	35%	27%	13%

There does seem to be evidence that a small flight to the light trap indicates a light field infestation. This is illustrated in Table V and, again, reference is made only to the Chatham light trap.

TARLE V. Years of low moth flight and low field infestations by the European corn borer in field corn, Chatham, Ontario.

Year	1954	1959	1962	1963
Light trap captures	122	149	112	193
Field infestation	8%	20%	6%	2%

In spite of the apparent relation between low infestation and relatively few moths captured at the light trap, it is apparent that this may not always hold (Table I). In 1960, for example, field infestation was only 13%, but 435 moths were captured at the light trap. But it is noteworthy that the smallest flight recorded at Harrow, 155 moths in 1954, coincided with a low infestation in the field, 12%. Quite probably, environmental factors, at the time of oviposition and larval establishment in the plant, have greater bearing on the ultimate infestation than the mere presence of moths. This is indicated by the work of Barlow and Mutchmor (1963).

Fluctuations in numbers of moths captured occurred at both traps but were greatest at Chatham where they ranged from a low of 61 captured moths in 1968 to a high of 1172 moths in 1956. This rise and fall of flight to the Chatham trap has been characteristic since its inception in 1932. In 1935, for instance, the figure was 162; in 1936 there were 735 moths, and in 1948 only 98 moths were captured.

At Harrow moth flight has generally been more predictable. Only in 1963 was there a noticeably low flight of moths (155) to the Harrow trap during the seasons when complete records were obtained.

A difference in sex ratio of captured moths was observed at the two traps under study. At Harrow there was generally a predominance of female moths; in fact, the males caught equalled the females in numbers on only one occasion, and they never exceeded them. At Chatham, on the other hand, the males always exceeded the number of female moths captured at the light trap during the period under study, sometimes by a very wide margin. Only once in the 35 years that the trap operated were female moths in excess of males; that was in 1948 when the ratio 58:42 favoured female moths. Ford (1955) states that light stimulates both sexes of moths equally. He postulates that females fly only after mating and then only between egg-laying periods, while males are constantly searching for females and are available for capture. He also states that males fly higher than females and are more readily caught in traps in high or raised positions. The Chatham trap was only slightly higher off the ground than the Harrow trap. However, the Chatham trap was situated in an area almost encircled by trees. The moths may have flown over the trees to reach the trap, if Ford's speculation is correct. Meanwhile, the sex ratio difference at the two traps remains an interesting but unexplained phenomenon.

Conclusions

The foregoing discussion indicates that the light trap, as used in this study, was a useful tool for finding initial, last, and peak dates of flight, as well as its duration. The numbers of moths captured did not necessarily indicate the degree of infestation in the field. A heavy moth flight did not point to a severe field infestation. There did appear to be a relation between a low number of captured moths at light traps and a light field infestation. The sex ratio was constant for each trap location, but each location was diametrically opposite as regards the sex that predominated. The trend toward multivoltinism, which was discussed in an earlier paper, was found to be irreversible. Second-generation moths now predominate in the total population, with the highest percentage found in the Harrow area. According to Dr. R. J. McClanahan of the Harrow Research Station (pers. comm.), there is now (1971) evidence of a partial third generation at Harrow. This was postulated by Wishart (1944) when he was studying parasitism of the corn borer in Essex County. The evidence then offered (1943) was meagre, but in the light of present day observations it proved to be correct.

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A RECORDING DEVICE FOR MEASURING RESPIRATORY MOVEMENTS OF AQUATIC INSECTS

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Abstract

A device for detecting and measuring respiratory movements of aquatic insects was designed and constructed. The apparatus is capable of instantaneously detecting and measuring undulating body movements.

* * * * * *

Introduction

Several insects make some respiratory movements in order to ventilate the tracheal system or gills. In many aquatic insects, locomotion alone acts as an important ventilatory mechanism, but others require some special mechanism in addition.

The nymphs of plecopterans (with gills) inhabiting streams and rivers use water current for irrigating their gills. However, when the water current is reduced, the nymphs resort to special undulating body movements so that freshwater and thus oxygen is still made available to the gills (Dodds and Hisaw 1924; Knight and Gaufin 1964, 1965).

Subjective descriptions of these body movements have been reported from time to time, but such descriptions could not be quantified accurately, nor were they made continuously over long intervals of time. During the course of my studies on the respiratory behaviour of plecopterans, a new automatic recording device was developed which is capable of instantaneously detecting, and measuring such movements. The present paper describes the apparatus and reports some of the results that can be obtained.

Materials and Methods

The apparatus consists of an activity chamber, an activity detector and a recording system (Fig. 1).

Activity Chamber

An activity chamber, D-shaped in section, 42 mm long by 13 mm at its widest was machined in a 38 mm diameter and 77 mm long Plexiglass cylinder (Fig. 2). The chamber is recessed in front to contain wiring to the strain gauges and has an outport which is closed with a 6-32 plastic screw. The outport serves as a vent when the activity chamber is being filled with water. Inlet and outlet canals (ϕ 5 mm) for water flow were drilled in two cylindrical blocks of Plexiglass. Each cylindrical block fits into the central Plexiglass cylinder containing the activity chamber and is sealed with 25 x 2 mm O-rings. The central cylinder has two guide pins of 3 mm diameter at each end which fit into the end cylindrical blocks of Plexiglass. This arrangement keeps the inlet and outlet openings in line with the center of the activity chamber.

Activity Detector

Strain gauges are used for sensing and measuring the respiratory body movements of a single animal. Four 350 Ω strain gauges (EA - XX - 125 B2 - 350, Intertechnology) were cemented, two on each side, at one end of a thin (.25 mm) 41 mm long and 9.5 mm wide stainless steel beam. The method of placement of gauges on a beam is illustrated in Fig. 3. The terminals of the four gauges were connected in a wheatstone bridge configuration (Fig. 4). To avoid instability and mechanical damage, the entire assembly was coated with a protective covering of polyurethane (M-coat A, Intertechnology). A stainless steel mesh (24 mm) long with one end bent to form an upright screen was glued with Epoxy to the upper surface of the beam. This provided substratum and restricted the animal to this area. The beam was screwed to the base of the inlet Plexiglass block, and when inserted into the chamber, it stretches across the chamber. The animal was introduced through the other end and the outlet block with a screen was slid into the central Plexiglass block. Aerated water was pumped into the insect chamber at a desired flow rate by a variable speed, peristalic pump (Harvard apparatus, model No. 600-1200). The outflow from the chamber can be passed through an oxygen electrode chamber for measurement of oxygen consumption, if desired.

Recording System

The components used for the recording system are: a Burr-Brown $\pm$ 15 Vdc dual power supply—Model 527; a Burr-Brown encapsulated low drift differential amplifier—model 3061/25 and a Perkin-Elmer self-balancing electronic recorder —Model 165. The circuit used is shown in Fig. 4. The power supply provides a

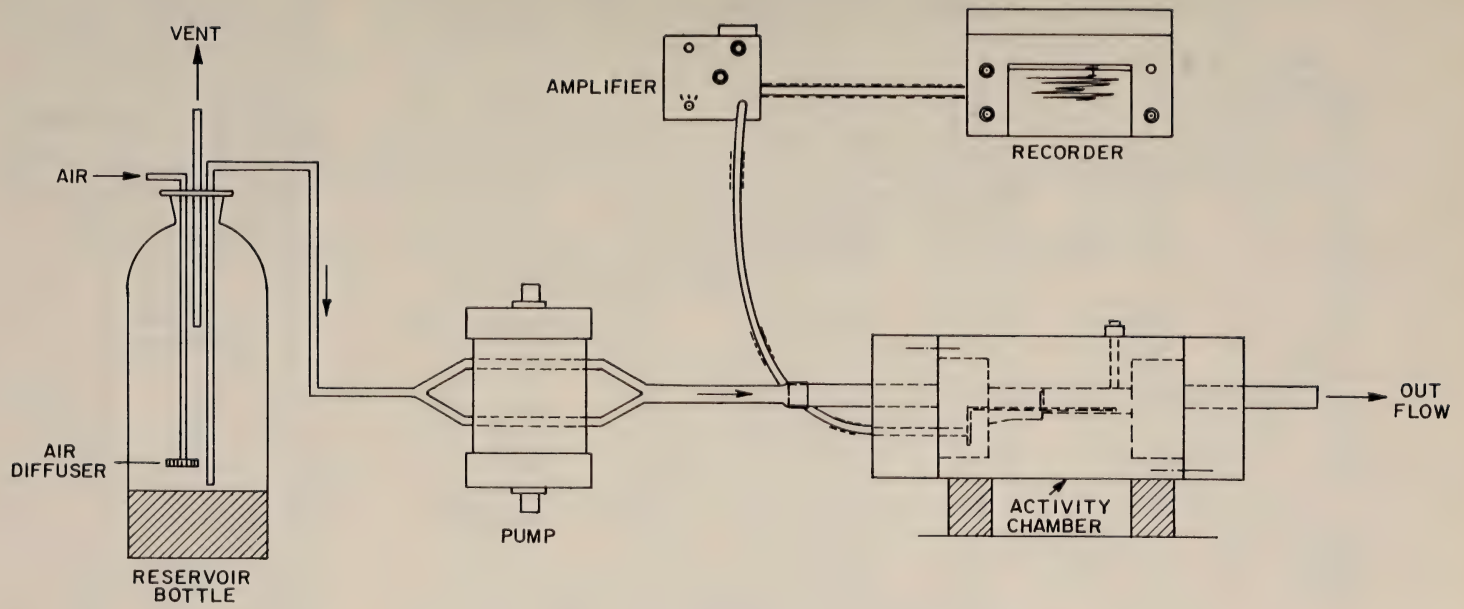

FIGURE 1. Diagram of apparatus used for measurements of respiratory movements of aquatic insects.

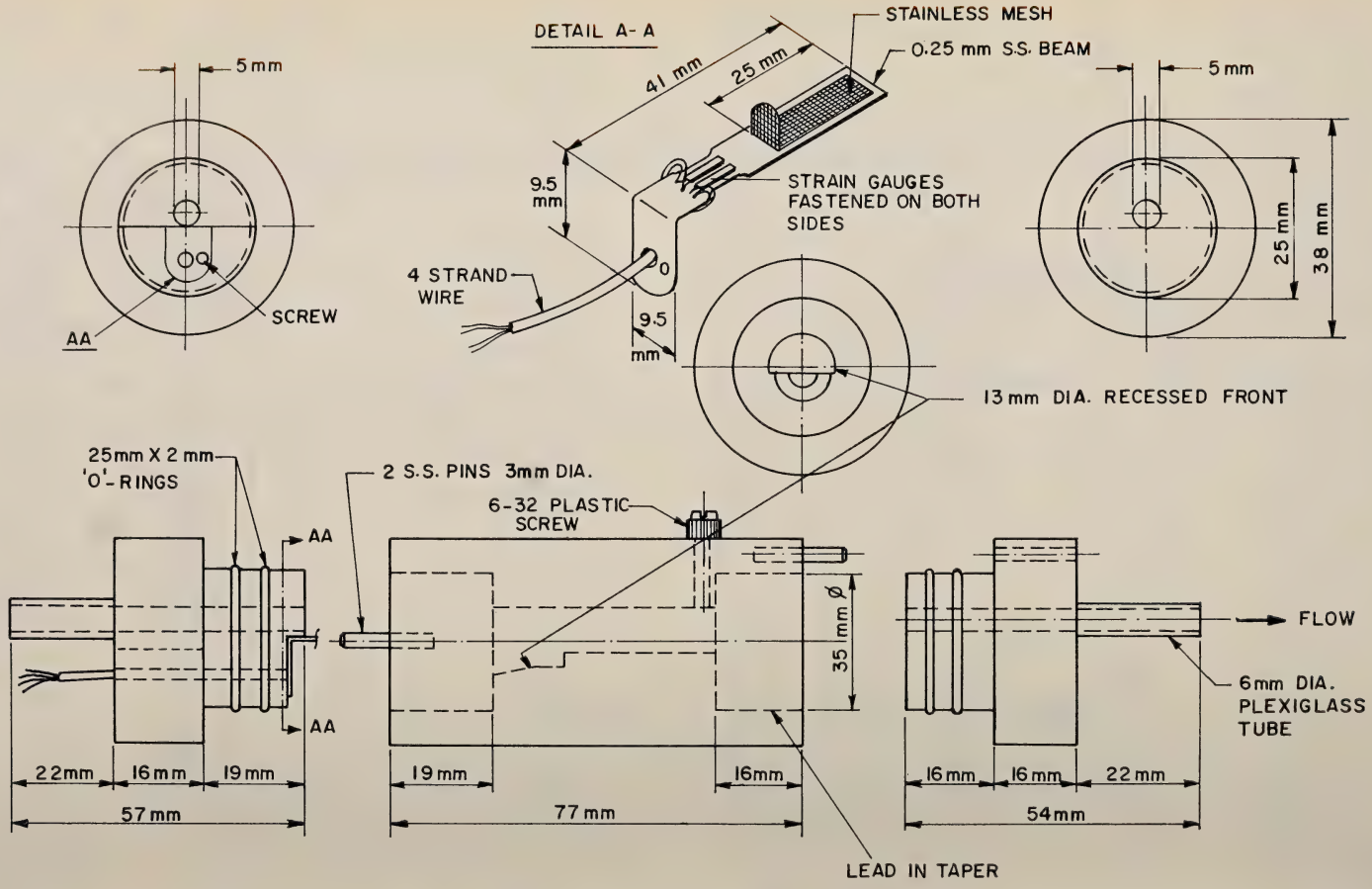

FIGURE 2. Details of the activity chamber.

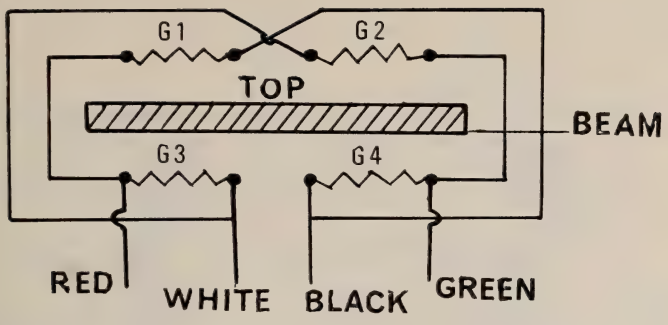

FIGURE 3. Arrangement of strain gauges on the beam.

direct steady potential of 6 volts across the strain gauge bridge. The output signal from the bridge is also a direct current, modulated by any change in the applied strain. The small signal output from the bridge can be amplified up to one thousand times by the amplifier in the circuit and recorded.

The recording system is balanced and zeroed as follows: The whole system is permitted to warm up for thirty minutes. With the input voltage selector switch of the recorder at 10 V/cm range, the recording pen is adjusted to zero by short-circuiting the recorder input terminal. Power supply to the amplifier is switched ON (SW_1) and the recorder is set at 5 mV/cm range. Next, zero input is provided to the amplifier (by depressing SW_3) and it is balanced to zero position on the recorder by adjusting the variable resistor R_{11}.

When the animal is still, the bridge is activated by closing the switch SW_2 and balanced for zero output to the recorder by fine and coarse controls R_9 and R_{10}. Adjustment of the resistor R_{12} provides feedback to reduce common-mode gain which is not critical.

Any subsequent movement of the animal, changes the sensor strain and unbalances the bridge. This results in a change in potential difference across the output of the bridge. The voltage difference, after amplification drives the recorder. A value proportional to the input voltage change is recorded on the chart while the recording chart is driven at a uniform speed provided by the synchonous motor of the recorder.

Results and Discussion

The movements of two species of Plecoptera, *Paragnetina media* and *Phasgnaphera capitata* were recorded with the apparatus. The nymphs of these two species make special 'push up' body movements when placed in still water. These movements involved contraction and distension of the legs in a vertical plane followed by contraction and distension of the abdomen at an angle. Similar observations have been made in several other species of Plecoptera (Knight and Gaufin 1964; McDiffett 1970; Benedetto 1970).

Animals made several movements of varying speed and duration. Correlation between direct visual observations and the recording showed that each voltage peak on the recording represent a ventilatory effort i.e. 'push up'. A sample trace of the animal activity is shown in Fig. 5. When movement begins the voltage changes, reaches a peak and when movement ceases, falls rapidly from the peak

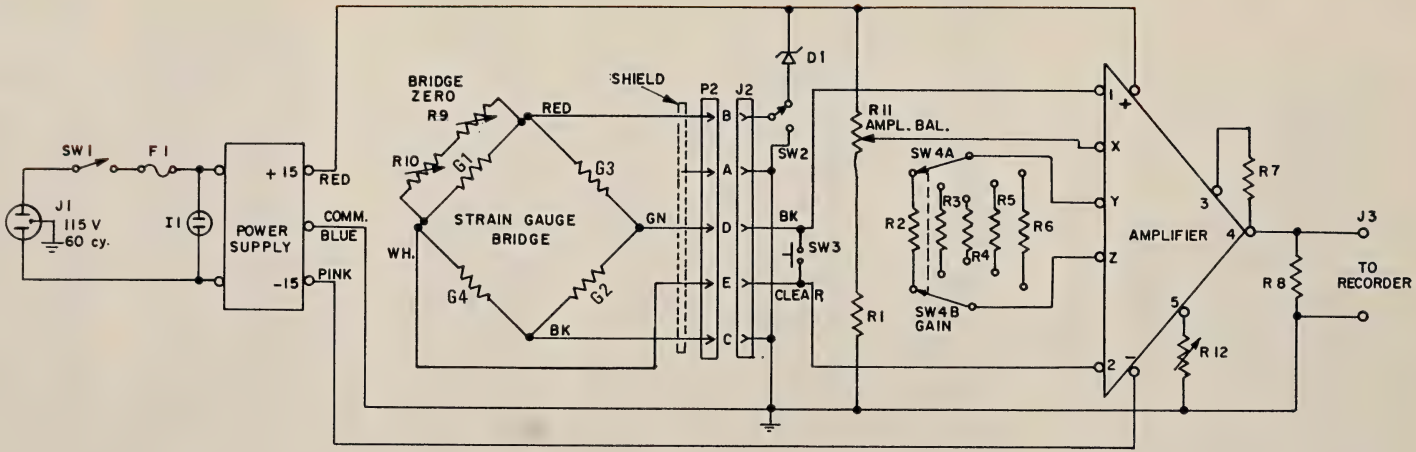

FIGURE 4. Strain gauge bridge amplifier circuit.

R1—56K ½W
R2—20K ½W
R3—40K ½W
R4—200K ½W
R5—2K ½W
R6—20K ½W
R7—22K ½W
R8—1.8K ½W
R9—500K Allen-Bradley
R10—50K Bourns 3359W
R11—50K Bourns 35015
R12—50K Allen-Bradley
D1—Zener Diode IN 4739 9.1 volts
G1-G4—Strain Gauges
SW1-SW4—Switches
J1-J3—Connectors
I1—Neon Lamp
F1—Fuse ¼ Amp.

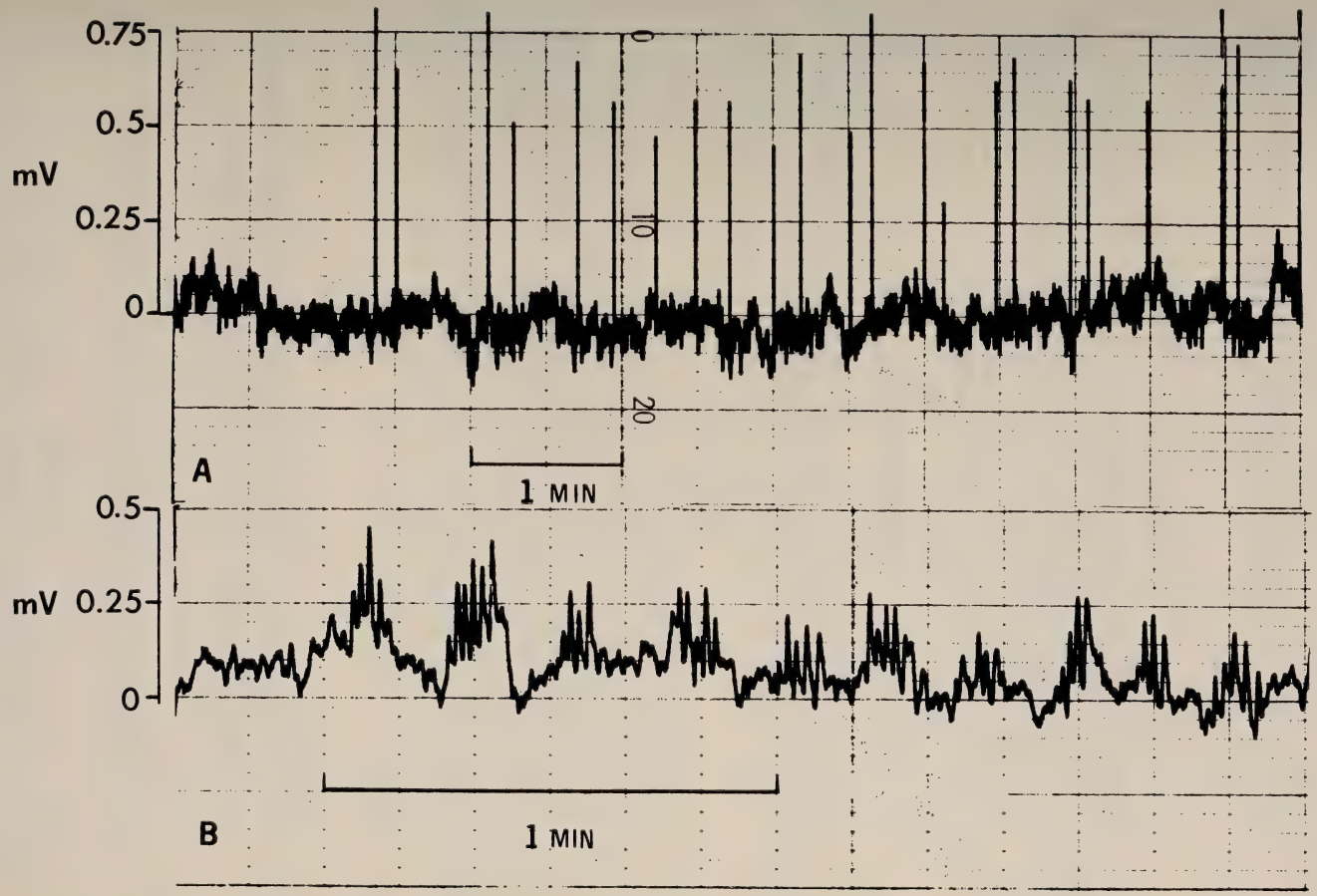

FIGURE 5 A sample trace of the respiratory movements. (a) *Paragnetina media;* (b) *Phasgnaphera capitata.*

to the inactive level. The greater the strain produced by any movement, the higher the peak voltage. The rate of movement is manifested by the number of peaks in a given time. The duration of each 'push up' may be recorded on a fast moving chart.

Paragnetina showed such 'push up' movements when the aerated water flow was reduced to 5 ml/min; the nymphs of *Phasgnaphera* performed such movements at a flow rate of 7 ml/min.

Inspection of the recording shows that *Paragnetina* made 'push up' movements at essentially regular intervals. In contrast, *Phasgnaphera* showed a burst of such movements, each burst occurring at a regular interval, consisting of 4-6 quick 'push ups'. It appears that these ventilatory movements take the form of alternating cycles of ventilation and cessation of movements. It may be that oxygen lack or rise in pCO_2 of the body provides a stimulus to initiate these movements. Presently, the apparatus is being used for the measurement of the respiratory activity of plecopterans under various environmental conditions. The activity of other aquatic insects can also be measured successfully.

Acknowledgements

The help of the staff of the Biology Workshop, University of Waterloo is greatly appreciated for making the apparatus. The financial support from the National Research Council of Canada is gratefully acknowledged.

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THE USE OF ARTIFICIAL POOLS IN ASSESSING POPULATIONS OF THE MOSQUITO *CULEX RESTUANS* THEOBALD

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Abstract

Artificial pools containing water borne bacteria of the family Pseudomonadaceae and treated with capric acid and NH_4NO_3 are attractive oviposition sites for two of the Ontario species of *Culex* mosquitoes *(C. pipiens* and, particularly *C.*

restuans). Large (1 m square) pools collect more rafts than small (0.09 m square) pools and are slightly more efficient at low population densities. However, the smaller pools are as effective as the large for monitoring *Culex* populations for the bulk of the season and are easier to install, maintain and service. Location of the pools (low damp areas along a stream course being best) is important if they are to be optimal indications of population density.

* * * * * *

Introduction

This paper describes the use of artificial pools as oviposition-traps (ovitraps) for monitoring populations of *Culex restuans* Theobald. Although it measures only the numbers of gravid females that have responded to artificial oviposition sites, the method is probably as effective as other trapping methods and offers certain advantages.

The female mosquito selects an oviposition site that ensures a high probability of progeny survival. If stimuli associated with preferred oviposition sites could be determined then alteration of certain sites could make them more attractive than unaltered ones and they could be used as trapping devices to measure population densities.

While testing the larvicidal properties of capric (decanoic) acid on mosquitoes in the field (Maw and House, 1971) it was found that pools treated with the acid subsequently became attractive oviposition sites (Maw, 1970). This phenomenon deserves further investigation.

Materials and Methods

Square pools of two sizes were used in the tests: (a) 1 m square, constructed of 2 x 6 in (5 x 15 cm) lumber with ⅛ in (4 mm) thick pressed hardboard bottoms and lined with polyethylene plastic film, (b) 30 cm square and 10 cm deep, constructed from 1 in scrap lumber and lined with polyethylene film. Eight of the large pools spaced 75 m apart, encompassing about 2 hectares (5 acres) and a grid of 21 of the small pools covering about 8 hectares (20 acres) were established in the wooded area of the Institute field station (Fig. 1). In addition, there were two sets of 16 pools (1 m square) in a four by four array on either side of the stream within the area (see Fig. 1). The latter were the pools described by Briand (1964).

The pools were filled with water from nearby streams or temporary natural pools. To each of the large pools were added 40 ml of capric acid dissolved in 15 ml of 95% ethanol, 10 ml of a saturated aqueous solution of NH_4NO_3, and one liter of water from pools that showed attractivity following capric acid treatment the previous year. This water had been frozen and contained the bacterial flora (Pseudomonadaceae) that utilizes the capric acid and generates the attractive factors (Maw, 1970). The small pools were treated proportionately. The two sets of 16 pools by the stream were not treated during this test and served as controls. Many of them had, however, been exceptionally good ovitraps following capric acid treatment during the previous year. The pools were maintained at peak efficiency by adding small amounts of capric (10 ml per large pool) when the water was losing its turbidity and becoming clear (Maw, 1970). Egg rafts were removed from the pools daily except Sunday. The test extended from June 4 to September 17. Species of hatching larvae was checked every two weeks.

Results and Discussion

A total of 9077 egg rafts were collected from the treated pools — 1962 from the small and 7115 from the large. No rafts were collected from the untreated pools until 20 August, and only a few sporadically after that date, 11 in all. This demonstrates the outstanding efficiency of the treated pools to attract ovipositing *Culex* mosquitoes. The control pools may have developed attractiveness late in the season due to increased rotting of organic material (dropping leaves, insects, etc.) and because the species complex changed from predominantly *C. restuans* to *C. pipiens* in late August.

It is probable that most of the females in the area seeking oviposition sites deposited rafts in the treated pools for, in addition to their by-passing the control pools, all the natural pools in the area were dry by June 24 and the large pond (Fig. 1) was completely dry by July 9. Neither *Culex* larvae nor rafts were found in natural pools.

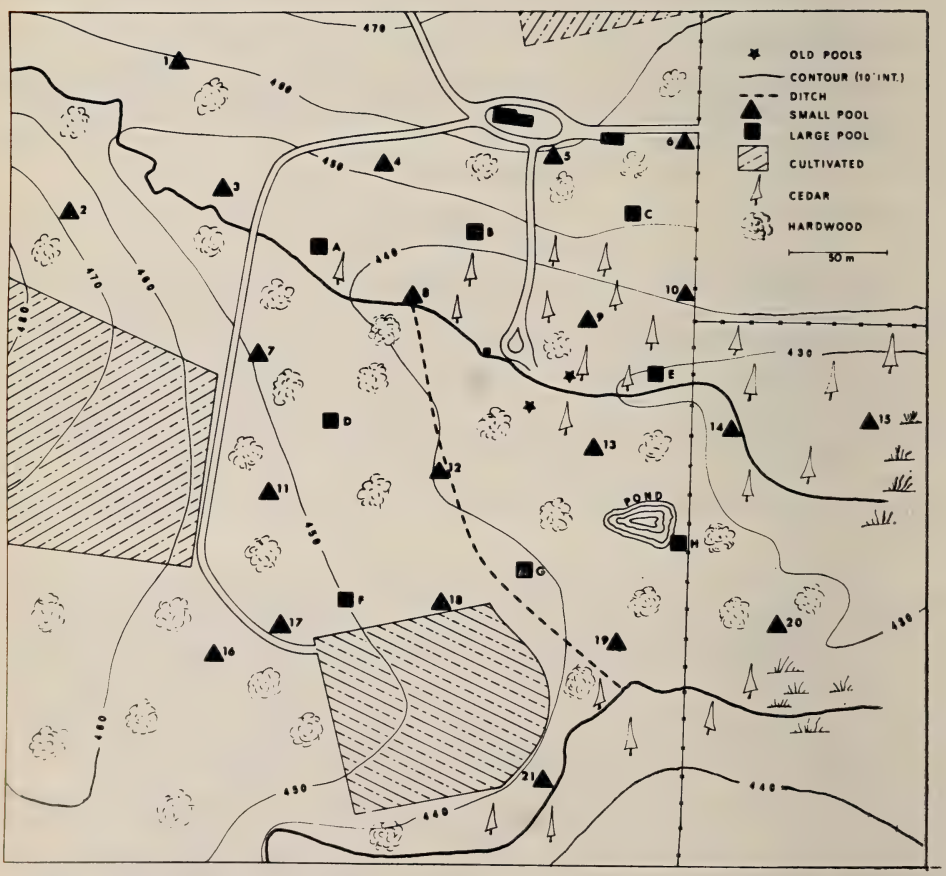

FIGURE 1. Location of artificial pools (ovitraps) at Institute field station.

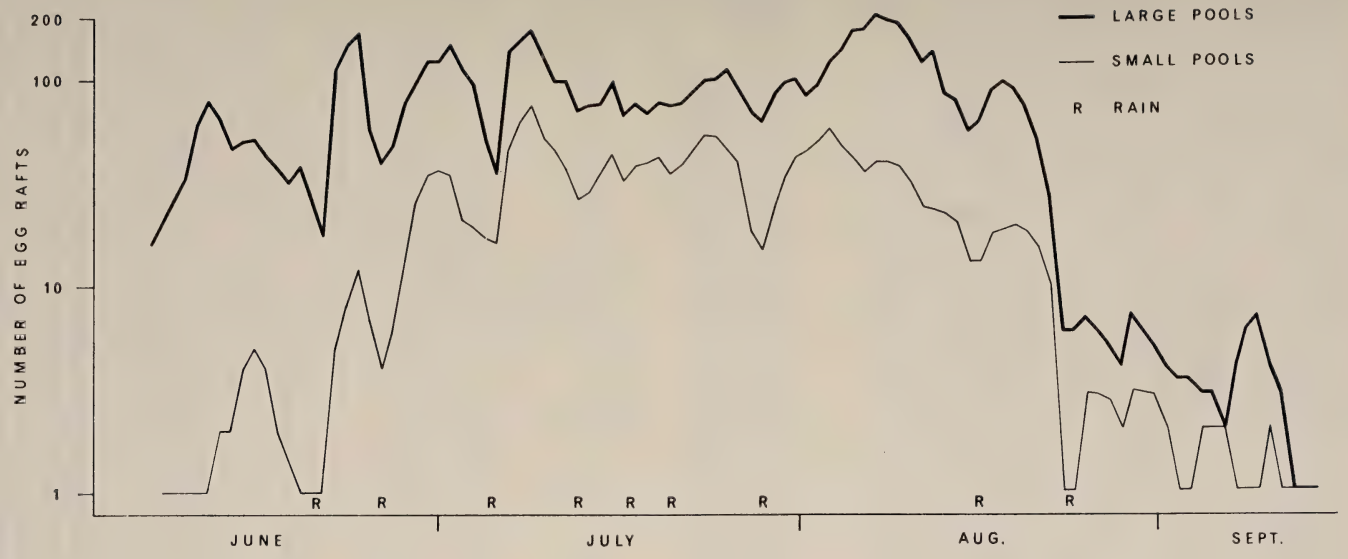

FIGURE 2. Comparison of seasonal egg raft collections (*Culex* sp.) in large and small artificial pools (ovitraps). Three day running mean plotted on logarithmic scale.

Although fewer rafts were laid in the small pools (mean 94.4, range 21-329) than in the large pools (mean 889.4, range 463-1394), there were more per area in the small pools — 0.10 rafts/cm^2 for the small against 0.09 rafts/cm^2 for the large pools. The temporal distribution of raft numbers taken daily from the small pools closely parallels that obtained for the large pools except for very early in June and from the second week in August (Fig. 2). Although the small pools are more easily installed, serviced, (egg rafts more easily seen and removed) and maintained, large pools may indicate population levels more reliably if there are small numbers of mosquitoes at some periods.

The performance of traps is influenced by their location. To show this, total raft collections for each of the 21 small pools and 8 large pools were ranked and divided into lower, middle and upper thirds. (The two lowest large pool collections were included in the lower third). The placement of the pools was then scored on a yes or no basis for two ecological considerations: the site was elevated and dry, the site was in a stream valley (slope toward a stream). The scores (Table 1) show that the locations of pools having smaller raft numbers (lower third) was predominantly in dry elevated areas off the stream valley; pools with largest raft numbers (upper third) had sites predominantly in low, damp areas, and in the slope to the stream ($P<.05$, Fisher exact probability test, Siegel, 1956).

Table I. The effect of two environments on the trapping efficiency of ovitraps.

Class	Pool size	n	Mean	Range	Environment			
					Dry elevated		Damp stream Valley	
					Yes	No	Yes	No
Lower third	large	2	492	463-521				
Lower third	small	7	42	21- 53	8	1*	1	8*
Mid third	large	3	773	661-916				
Mid third	small	7	76	60- 95	5	5	4	6
Upper third	large	3	1257	1136-1394				
Upper third	small	7	163	99-329	3	7*	7	3*

* Significant at 5% level

Egg rafts obtained in early June probably were laid by females that survived winter hibernation. Thus ovitraps are probably more effective in assessing overwintering populations of *C. restuans* than were the light traps used by Belton and Galloway (1966) who claim that they did not notice overwintering females in their catches. Because females are actively seeking oviposition sites ovitraps are functionally comparable to animal-baited traps that catch blood seeking females but ovitraps as described here are undoubtedly easier to service than animal-baited traps.

The ovitrap method may be a sensitive indicator of flight activity. For example, inferring that oviposition does not occur without flight, the sharp decrease in numbers of egg rafts for daily collections shown in Fig. 2 coincide in all instances with rainfall that occurred during the early morning hours and continued until at least 1000 hours. Rainfall occurring after 0900 or 1000 hours and stopping before dawn the following day had little effect on oviposition provided temperatures remained above 10° C.

Acknowledgements

The authors are grateful to Mr. C. F. Nicholls for preparing the illustrations and to Mr. R. H. Kempster who with a pair of enthusiastic university students contributed immeasurably to the construction and maintenance of the artificial pools and gathering of data.

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DISCRIMINATION BETWEEN PARASITIZED AND UNPARASITIZED HOSTS BY *PLEOLOPHUS BASIZONUS* (HYMENOPTERA: ICHNEUMONIDAE)

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Abstract

Although *P. basizonus* females do not discriminate between unattacked hosts and those containing eggs of their own species, they do show a strong rejection of hosts containing later developmental stages. The rejection is largely caused by the presence of the developing parasite, although the partially consumed host also plays a role. It is shown that this behaviour can be accommodated in existing submodels developed by using this parasite.

* * * * * *

Introduction

Pleolophus basizonus (Grav.) is a common and widely distributed parasite of diprionid sawflies in Europe (Pschorn-Walcher, 1967). Nearly a half million adults of this species were released in the Maritimes, Quebec, Ontario and Manitoba from 1939 to 1949, against several exotic and native diprionids (McGugan and Coppel, 1962), but it was not until 1958 that its establishment was confirmed by recoveries from *Neodiprion sertifer* (Geoff.) near Chatsworth, Ontario (Griffiths, 1961). Since then, Rose and Sippell (1966) showed that the species is present throughout the range of *N. sertifer* in southwestern Ontario and Grifffiths *et al.* (1971) reported that it has been recovered from two other introduced and seven native sawflies elsewhere in the province.

A great deal has been learned about the biology and behaviour of *P.basizonus* recently and several submodels have been developed to describe its reaction to its own and to its host's density (Griffiths, 1969a; 1969b; Griffiths and Holling, 1969). Thus *P. basizonus* is an ideal candidate for planned studies on the short-term quantitative effects of the release of established parasites on the course of local outbreaks of sawflies. However, the developed submodels make the naive assumption that the parasite's reaction to previously attacked hosts is the same, irrespective of the developmental stage of the contained parasite. The purpose of this preliminary study is to establish whether this assumption is correct, and, if it is not, whether changes in the submodels are required to accommodate the more realistic situation.

Methods

The adult parasites used in this work came from stock that has been maintained in the laboratory for a number of years with periodic additions of wild adults. All rearings, experiments and observations were carried out with parasites in 4- x 4- x 4-inch cages, kept at approximately 20°C, 50 to 60% relative humidity and 16-hour photophase. Hosts, which were female *N. sertifer* prepupae in cocoons, were reared in the same room after 24 hours' exposure to attack. Under these conditions, emergence of the next parasite generation usually started 3 weeks after hosts were removed from the cages.

The adult female parasites used in experiments and observations were all standardized, that is, they were at least 3 days old, had spent that time with a male and had oviposited during that period. Approximately equal numbers of females of each age up to a maximum of 11 days were used in each set of experiments. Thus, all females were at the peak of their oviposition activity (Griffiths, 1969b). All host cocoons for use in experiments were opened before being offered to parasites, and only those containing living parasites or living sawfly eonymphs were used. All offered hosts were numbered with India ink, so that individuals could be identified after exposure to attack. Controls consisted of opened, numbered, but previously unoffered hosts. All days on which experiments were carried out or on which controls only were offered were preceded and followed by at least one day when 10 unopened, unnumbered female cocoons were offered to the parasite. Attacked hosts obtained on these days were the source of developing parasites for use in experiments. All of these, except those for the 0- to 1-day-old age-group tests, had all but one egg removed when they were examined after attack.

Four sets of experiments were carried out. To avoid repetition, the description of each set has been presented with the results of the experiments.

Results

In the first set of experiments, females were offered four previously unexposed hosts and four hosts containing developing *P. basizonus,* all of the same known age. After 24 hours' exposure, hosts were removed and examined for attack. Eight age groups of immature *P. basizonus* were used, and the number of replicates in each age group varied between 25, when results were not clear cut, and 11, when they were. The mean daily oviposition rate of these females did not differ significantly from that obtained in the controls (Table I), indicating that the parasites showed no reluctance to oviposit when confronted with a group of hosts half of which contained immature stages of their own species. However, the presence of immature parasites had an increasing influence on the distribution of

eggs among hosts as the age of the developing parasites increased. When the previously attacked hosts contained only eggs 1 day old or less, the parasite did not avoid attacking them, as shown by the value of chi^2 in Table II. This value was obtained when the observed number of eggs per host in the two categories was compared to that predicted if no difference in acceptability existed between them. In the 1- to 2-day-old age group, in which there were 95 eggs and five first-instar larvae at the beginning, but only 19 eggs and 81 first instars 24 hours later, the parasites' discriminatory ability had already become evident, as indicated by the highly significant chi^2. Chi^2 is significant in all the subsequent groups tested, but the parasites continued to make a few "errors" until the contained parasite larvae were in the fourth instar, when their discriminatory ability apparently became perfect.

Because none of the eggs oviposited in the hosts before the start of the 0- to 1-day-old age-group tests was removed, these data may be broken down by the number of eggs they contained when the tests began, to obtain a closer look at the females' behaviour. There was no difference in attack between those hosts that started the tests with no eggs and those that started them with only one egg (Table III). However, hosts that had more than one egg on them at the beginning of the test had significantly more eggs laid on them during the test than either of the other two categories. Whatever made those hosts more acceptable for oviposition on the first day continued to operate to concentrate eggs in them on the second day.

The second set of experiments consisted of 2-hour observations of the behaviour of female parasites when they were offered cocoons. Only standardized females that had oviposited in the previous 24 hours were used, and data on females that did not oviposit in the 24 hours following the observations were re-

TABLE I. Numbers of eggs laid per day by female *Pleolophus basizonus* when offered previously unexposed hosts and hosts containing *P. basizonus* of various ages.

Type of host	N	Eggs per female per day Mean ± S.E.	"t"[a]
Controls = previously unexposed only	65	3.37 ± 0.25	
Previously unexposed and 0- to 1-day-old *P. basizonus*	23	4.39 ± 0.40	2.15
Previously unexposed and 1- to 2-day-old *P. basizonus*	25	3.36 ± 0.35	0.02
Previously unexposed and 2- to 3-day-old *P. basizonus*	20	3.00 ± 0.52	0.70
Previously unexposed and 4- to 5-day-old *P. basizonus*	15	3.27 ± 0.53	0.18
Previously unexposed and 8- to 9-day-old *P. basizonus*	13	3.38 ± 0.54	0.03
Previously unexposed and 12-to 13-day-old *P. basizonus*	13	3.38 ± 0.47	0.03
Previously unexposed and 16- to 18-day-old *P. basizonus*	11	4.18 ± 0.64	1.24
Previously unexposed and 20- to 21-day-old *P. basizonus*	14	3.43 ± 0.46	0.10

[a] "t" values obtained from comparison with controls.

jected. Females were deprived of hosts for 6 hours before the observations were started to increase the probability of attack during the observation period. Two opened, numbered cocoons were offered at each of 59 observations. In approximately half of the observations, both cocoons contained developing *P. basizonus,* and in the remainder both cocoons contained only live *N. sertifer* prepupae. During the observations, records were kept of the time spent in contact with the cocoons, the number of insertions of the ovipositor and the time it remained within the cocoon. Information on the number of eggs laid was obtained by examining the cocoons afterwards.

Females whose oviposition behaviour was observed for 2 consecutive hours showed the same reaction to the different types of hosts offered as noted in Table II. Twenty-one of the 30 females presented with previously unexposed hosts

TABLE II. Comparison of attack by *Pleolophus basizonus* females on previously unexposed hosts and hosts with various developmental stages of *P. basizonus* on them.

Hosts with developing *P. basizonus*			Previously unexposed hosts		Chi^2
Age of developing parasite at start (days)	No. hosts offered and stage of developing parasite[a]	No. eggs laid	No. offered	No. eggs laid	
0-1	71 eggs	40	112	61	0.03
1-2	95 eggs, 5-I	15	100	69	34.71**
2-3	5 eggs, 75-I	2	80	58	52.27**
4-5	1-I, 17-II, 37-III	2	63	47	35.62**
8-9	1-III, 10-IV, 36-V	0	56	44	36.93**
12-13	1-V, 12-eon, 36-pro	0	55	44	39.20**
16-18	1-V, 1-pro, 37-pupae	0	49	46	36.62**
20-21	54 pupae	0	55	48	47.13**

[a] I, II, III, IV, V = first-, second-, third-, fourth-, fifth-stage larva, respectively.
eon = eonymph
pro = pronymph
**p less than .001

TABLE III. Number of eggs laid per host by female *Pleolophus basizonus* on hosts which had 0, 1, and more than 1 egg laid on them in the previous day.

No. eggs/host at end of first day's attack	N	No. eggs/host laid during second day's attack	"t"		
		Mean ± S.E.	0 vs. 1 egg	0 vs. >1 egg	1 vs. >1 egg
0	126	0.54 ± 0.08	1.15		
1	56	0.39 ± 0.09		2.99*	
>1	15	1.27 ± 0.30			3.84*

* p less than .01

oviposited, laying a total of 43 eggs. There were no ovipositions by 14 females presented with hosts containing second- or third-instar *P. basizonus* and none by 15 females offered hosts with *P. basizonus* prepupae or pupae in them.

More detailed analysis of observation data indicated something of the discrimination technique of the parasite. First, the number of times female parasites contacted hosts did not differ when (a) oviposition did occur in *N. sertifer* prepupae, (b) *N. sertifer* prepupae were offered but not attacked, or (c) *P. basizonus* larvae, prepupae or pupae were offered. The level of activity of the female parasites was, therefore, the same in the presence of previously attacked hosts as in their absence. Further, the decision to accept or reject a host was apparently not made at a distance, but required contact with the host cocoon.

Since the decision apparently required mounting the cocoon, the amount of time spent on cocoons containing various contents was determined (Table IV). The figures are the mean length of time spent on the cocoon, and are admittedly a crude measure of the time required to make decisions. However, it is impossible to get a more accurate measure, since, except when oviposition results, it cannot be known in which of the numerous contacts the decision is made, or, indeed, whether more than one decision was made on a cocoon during the observation period. The obviously longer average mounted period on hosts that were attacked was largely the result of the prolonged oviposition procedure. In these observations, the mean oviposition period was 26.6 $\pm$ 2.20 minutes, essentially the same as the 21.3 $\pm$ 1.16 minutes reported in an earlier paper (Griffiths, 1969a). The mean mounted time for rejected hosts containing *N. sertifer* prepupae was not different from that for hosts containing *P. basizonus* larvae. The much shorter time spent on *P. basizonus* prepupae and pupae suggests that the decision to reject a cocoon is made more quickly when the contents are almost exclusively *P. basizonus* than when the contents are largely or completely *N. sertifer*.

One final characteristic of the decision-making process obtained from these observations is that insertion of the ovipositor into the host cocoon is not necessary for rejection. There were no ovipositor insertions in any of the 29 observation periods in which parasite females were offered only hosts containing *P. basizonus,* nor in those instances where *N. sertifer* only were offered but not attacked.

In the third set of experiments, hosts parasitized 2 to 3 days previously, the first-instar larvae from them, and previously unexposed hosts were offered to female parasites in various combinations to determine which of the several elements involved was contributing to selection and rejection. The mean number of eggs laid per female in these experiments again did not differ statistically from that obtained in the controls, and, as in the earlier group of experiments, there were

TABLE IV. Mean length of time spent by *Pleolophus basizonus* females on host cocoons of various types.

Type of host	N	Mean $\pm$ S.E. (sec.)
Neodiprion sertifer — with oviposition	164	470 $\pm$ 64
N. sertifer — no oviposition	141	39 $\pm$ 13
P. basizonus larvae	131	31 $\pm$ 16
P. basizonus prepupae and pupae	140	9 $\pm$ 2

marked differences in distribution of eggs among the various categories of hosts offered. In the first tests, female parasites were offered a choice of live, previously unexposed hosts and 2- to 3-day-old paralyzed hosts which had had the parasite eggs removed within 24 hours of their deposition. There was no significant difference in attack between these two types of host (Table V). In the second tests, first-instar larvae were transferred immediately before each test to previously unexposed live hosts and the parasites' reactions to them and to the paralyzed hosts from which the first instars had been removed was compared. There was an avoidance of paralyzed hosts and a concentratin of eggs in the previously unexposed hosts with first-instar larvae on them, although the number of eggs per paralyzed host (0.17) was considerably higher than that oviposited on 2- to 3-day-old larvae earlier (0.025, Table II). In these experiments, roughly 17% of the transferred first-instar *P. basizonus* larvae died during the 24 hours of the test, and an equal number disappeared from the host cocoons. The hosts in which this occurred were obviously acceptable to the female adults, since an average of 1.2 eggs per host was laid on them, significantly greater than that on either of the other two categories (Table V). Because of this difference, another test was run in which the female parasites were offered a choice of live, previously unexposed hosts on which first-instar larvae had just been placed, and live previously unexposed hosts only. Under these conditions there was a significant avoidance of attack on those hosts that had living, first-instar larvae on them and also on those that had dead first instars and from which first instars had escaped.

TABLE V. Comparison of attack by female *Pleolophus basizonus* on hosts parasitized 2 to 3 days previously, the first-instar larvae from them, and previously unexposed hosts, in various combinations.

Test no.	Type of host (no. offered in brackets)	No. eggs laid	Type of host (no. offered in brackets)	No. eggs laid	Chi^2
1	Paralyzed host only, eggs removed at time of oviposition (61)	28	Previously unexposed host (65)	42	1.98
2	Paralyzed host only, first instar removed at start of test (64)	11	Previously unexposed host with first instar added at start of test—I live at end of test (43)	23	10.66***
	Paralyzed host only, first instar removed at start of test (64)		As above—I dead at end of test (11)	13	29.92***
	Paralyzed host only, first instar removed at start of test (64)		As above—I missing at end of test (10)	12	29.40***
3	Previously unexposed (67)	50	Previously unexposed host with first instar added at start of test—I live at end of test (37)	13	6.13**
	Previously unexposed (67)		As above—I dead or missing at end of test (24)	7	5.83*

*p = .02
**p = .01
***p = approx. .001

In the fourth set of experiments, standardized females were offered eight opened, numbered, but previously unexposed hosts for two consecutive days. In half of the 48 replicates, the hosts were examined after 24 hours, records of the number of eggs laid were obtained, and hosts were returned with all eggs still present for a second 24 hours of attack. The remaining half of the replicates were left undisturbed for 48 hours before examination. Those tests in which hosts were examined and returned to the cages after 24 hours' exposure have been called "1 + 1-day" tests to distinguish them from the "2-day" tests in which hosts were left undisturbed for 48 hours. In the 1 + 1-day tests, the mean number of eggs laid per host did not differ on the two days (Table VI), and on both days the distribution of eggs per host was adequately described by the negative binomial equation but differed significantly from the distribution predicted by the Poisson equation. When the total attack per female on both days in the 1 + 1-day tests was compared with the results of the 2-day tests, there was again no difference in attack (Table VI).

The exploitation submodel developed by Griffiths and Holling (1969) gives the number of hosts attacked as the difference between the number of hosts offered and the number not attacked. Thus its descriptive power can be tested simply by comparing the observed number of hosts not attacked and attacked with the zero and one-minus-zero categories of the appropriate theoretical distribution. The form of the submodel utilizing the negative binomial equation provides predicted numbers of hosts attacked that are extremely close to those observed in all four sets of data (Table VII). The form based on the Poisson

TABLE VI. Comparison of eggs laid per female *Pleolophus basizonus* in 1 + 1-day and 2-day experiments.

Type of data	N	Mean ± S.E.	"t"
1 + 1-day experiment			
Day 1	25	3.76 ± 0.37	1.10
Day 2	25	4.36 ± 0.40	
Day 1 + 2	25	8.12 ± 0.53	0.42
2-day experiment	24	7.79 ± 0.57	

TABLE VII. Chi^2 obtained when observed zero and one-minus zero classes are compared to those predicted by the negative binomial equation.

Type of data	Zero class		(One - zero) class		Chi^2
	Observed	Predicted	Observed	Predicted	
1 + 1-day expt					
Day 1	126	127.188	71	69.815	0.03
Day 2	125	119.354	72	77.646	0.68
Day 1 + 2	81	82.824	116	114.176	0.07
2-day expt	78	84.070	114	107.930	0.78

equation gives predictions which, although again not significantly different from observations, are not as close to the observed figures as those provided by the negative binomial (Table VIII).

TABLE VIII. Chi^2 obtained when observed zero and one-minus-zero classes are compared to those predicted by the Poisson equation.

Type of data	Zero class		(One - zero) class		Chi^2
	Observed	Predicted	Observed	Predicted	
1 + 1-day expt					
Day 1	126	122.267	71	74.733	0.30
Day 2	125	113.319	72	83.681	2.83
Day 1 + 2	81	70.330	116	126.670	2.52
2-day expt	78	72.493	114	119.507	0.67

Discussion

The inability of *Pleolophus basizonus* females to discriminate between hosts containing parasite eggs and unattacked hosts, leading to superparasitism has been recorded previously (Griffiths, 1961; Griffiths and Holling, 1969). The ability to detect later parasite stages and to avoid attacking hosts containing them has not been previously recorded.

Many of the possible cues to which the female parasite could be reacting in rejecting hosts with developing parasites in them can be eliminated. It cannot be an odour left by an earlier attack, which prevents repeated attacks in *Trichogramma evanescens Westw.* (Salt, 1937), since, in *P. basizonus,* previously attacked hosts are frequently attacked again until egg hatch occurs. Movement within the host cocoon cannot be the stimulus involved. Unattacked *N. sertifer* prepupae move actively, but in the frequently noted secondary attacks, the host prepupa is paralyzed and incapable of movement. The paralyzed host itself has no influence on the parasite's decision, as shown in the first tests listed in Table V, but apparently even a small amount of feeding on the host is enough to decrease its acceptability markedly, since such hosts were the least attacked in the second tests in Table V. These tests also showed that the odour or repellent cue of the living first instar dissipates very quickly, since hosts in which the first instar died or disappeared were the most acceptable of the four categories offered in the second tests. This conclusion strengthens the idea that it is the act of feeding rather than the former presence of the first instar that caused paralyzed hosts to be rejected in the second tests. The restraint of parasite females is limited, apparently, and in a situation such as that presented in the second tests, females are selecting hosts not by an all-or-nothing process but by a balancing of attractive and unattractive cues. When given an opportunity to oviposit in the type of hosts normally selected, as in the third tests (Table V), they show a strong and equal rejection of hosts containing both living and dead first-instar parasite larvae. These experiments show that the primary cue is the presence of the living parasite and that the partially consumed host also plays a small but important role. This hypothesis is supported by the observation that rejection time is shorter when the host contents are largely or completely

P. basizonus than when only a small proportion of the host cocoon contains *P. basizonus* (Table IV), and also by the decreasing number of "errors" with increasing size of *P. basizonus* (Table II). The cue is clearly an olfactory one since penetration of the host cocoon is not necessary to make a decision, but it is evidently a quite subtle one, since contact with the host is necessary to make it and since parasite females make their decisions accurately when confronted with numerous hosts of different types all confined within a small cage.

As stated earlier, superparasitism by *P. basizonus* was recorded by Griffiths and Holling (1969) in a large series of 24-hour experiments involving 4200 parasite days. In these experiments the reactions of *P. basizonus* adult females to hosts containing eggs of their own species was firmly established. They not only did not avoid previously attacked hosts, but distributed their eggs contagiously among them. The submodels developed in these papers were thus based on 24-hour experiments and on the assumption that failure to discriminate between attacked and unattacked hosts applied to all developmental stages of parasites within hosts. In other words, all days were alike. The present paper justifies this naive assumption in part by showing that the sum of 2 days' continuous attack on the same hosts can be described by the sum of the attack of two separate days, but it also shows that such an assumption is biologically incorrect if the number of days exceeds the incubation period of *P. basizonus* eggs. This period ranges from approximately 11 days at 5.5°C to 1.5 days at 30°C (Griffiths, 1969b), and Griffiths and Holling (1969) have provided a submodel (equation 10) which could, with little modification, be used to allow for attack for periods such as these.

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AN ACCOUNT OF THE NORTH AMERICAN SPECIES OF *EUPHORIELLA* ASHMEAD WITH DESCRIPTIONS OF SEVEN NEW SPECIES (HYMENOPTERA: BRACONIDAE, EUPHORINAE)

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Abstract

Three Nearctic species of the braconid genus *Euphoriella* Ashmead are redescribed. Seven other species are described and the 10 known species are keyed. Generic relationships and structural characters of use for separating species of *Euphoriella* are briefly discussed.

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Introduction

The genus *Euphoriella* was raised by Ashmead (1900) to contain a braconid then known as *Labeo incertus* Ashmead. Two other Nearctic species have since been described, *pacifica* Muesebeck (1936) and *sommermanae* Muesebeck (1956), but otherwise the genus has remained one of the least known of the Euphorinae.

Species of *Euphoriella* were reared or field-collected at Belleville during work on the biosystematics of euphorine Braconidae. Attempts to identify this material led to a study of types and other specimens in the Canadian National Collection, Ottawa, the United States National Museum, Washington, and the British Museum (Natural History), London, and some of the results of this study are reported in this paper. A subsequent paper will give the results of a survey of *Euphoriella* host associations in the Belleville district and also descriptions of some Ottawa, Washington and Belleville material not included here.

Little is known of the biology of *Euphoriella.* Its host range appears similar to that of *Leiophron* Nees, which attacks Heteroptera: Miridae (Bilewicz-Pawinska 1964, 1968, 1969; Brindley 1939; Clancy and Pierce 1966; Lean 1926; Loan 1965, 1966, 1970; Machalova 1954; Menzel 1924, 1926; New 1970; Richards 1967; Streams *et al,* 1968; Waloff 1967; Wilkinson 1926) and Psocoptera (New 1970; Richards 1967). So far, however, North American species have been bred only from psocids (Muesebeck 1963; Sommerman 1956). The associations given here and our unpublished data indicate a preference for psocids, and similarly, a preference of *Leiophron* for mirids. A possible exception may be *E. marica* Nixon, which was reared by Taylor (1945) from a *Sthenarus* mirid in Uganda, and described by Nixon (1946). Because of its closed radial cell, 13-segmented antennal flagellum, and host association this species may be more accurately placed with *Leiophron.*[3]

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[3] The tergite 1 of *E. marica* is fused beneath indicating that it is correctly placed in *Euphoriella.*

Structurally, *Euphoriella* appears closely related to *Leiophron apicalis* Haliday, the type species of *Leiophron*: the mesontonum is smooth, venation is reduced, and male genitalia are similar. Its species, however, are more homogeneous than those of the *apicalis* species group e.g. all known species have a 12-segmented flagellum and remarkably uniform wing venation. Such characters and the apparent restriction of *Euphoriella* to the Nearctic region and to psocids are enough to establish its generic entity. The important morphological characters of *Euphoriella* and *Leiophron* are listed in the following key.

1. Prescutal sutures impressed, mesonotum at least partly punctate; parameters of genitalia not prolonged beyond aedeagus and not longer on ventral than dorsal side ....*Leiophron* Nees (*pallipes* Curtis species group)[4]

   Mesonotum smooth, prescutal sutures effaced or only lightly impressed anteriorly; parameres of aedeagus extended beyond aedeagus and longer on ventral than dorsal side 2

2. Flagellum exceeds 12 segments; radial cell complete, typically very narrow at wing margin; tergite 1 not fused beneath ....*Leiophron* Nees (*apicalis* Haliday species group)

   Flagellum 12-segmented; radial cell absent, second abscissa of radius spur-like at wing margin; tergite 1 fused beneath .... *Euphoriella* Ashmead

Most of the species reviewed or described in this paper are remarkably similar. Useful specific separation characters are the length of the longest marginal cilia of the hind wing (noted by Muesebeck 1936), the color of the flagellum and legs, the length and width of the eye, the width of the face, the length of the hind tibia, and the lengths, widths and lengths to width ratios of the basal five antennal segments. Variation of these characters in the species examined is low (Tables I-III); but the ranges of values for some species overlap and sometimes render the identification of isolated specimens uncertain.

The eye dimensions, face width, and lengths of the basal five antennal segments were measured as shown (Figures 1-3). Definition of some other terms used in the species key and descriptions are as follows: malar space, the length of the malar suture; flagellum length, the total length of the antenna beyond the pedicel including intersegmental regions; head width, the distance from the lateral margin of the eye to that of the other across the frons; head length, the distance from the antennal sockets to the occipital carina; stigma length, the length from the apex of the parastigma to the apical costal junction; tergite I length, the length of the dorsal face from the propodeum to the apical margin. Measurements of antennal segments and wing characters were made from permanent slide mounts by removing the dry antenna or wing and mounting directly in Diaphane.

The sex of *Euphoriella* individuals is not easy to determine from genitalia without dissection, as the genital structures are often retracted into the gaster.

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[4]This species group may warrant generic status.

Useful secondary characters that render such dissection unnecessary are found in the flagellum, face, eye and (in some species) color. In general, the flagellum of the male is longer and its apex not as wide as that of the female; the eyes of the female are larger and their convergence on the face is more pronounced than in the male. This results in the face of the female being usually very narrow, often less than the width of an eye, whereas the face width of the male usually exceeds the eye width. In two new species described here, the legs of the female are yellowish and those of the male infuscated.

Types of new species are in the Canadian National collection, Ottawa (CNC), U.S. National Museum, Washington, D.C. (USNM) and Br. Mus. (Nat. Hist.), London (BM) as noted.

Key to Described Species of *Euphoriella* from North America

1. Hind wing narrow or straplike, longest marginal cilia 0.4 to 0.6 times wing width 2

   Hind wing broad, longest marginal cilia about 0.3 times wing width 10

2. Tergite I slender, more than 4.0 times as long as apical width; distinctly bicolorous, head pale reddish; large species, hind tibia 0.61 mm long; length to width ratio of flagellar segment I 3.3:1.0 (♂)....*Euphoriella nixoni* new species

   Tergite I less than 4.0 times as long as apical width; body not distinctly bicolored; smaller species; flagellar segment I not as long 3

3. Males 4

   Females 8

4. Hind femur and tibia infuscated 5

   Hind femur and tibia yellowish 6

5. Scape 1.9 to 2.5 times as long as wide; pedicel much shorter than flagellar segment II, about equal to I or III; flagellum yellowish ....*Euphoriella kaladarensis* new species

   Scape 1.5 to 2.0 times as long as wide; pedicel about as long as flagellar segment II or III, longer than I; flagellum chiefly dusky..... .....*Euphoriella solidaginis new species*

6. Flagellum cinerous or dusky, lighter basally; legs clearly yellow; body dark reddish brown ....*Euphoriella sommermanae* Muesebeck

   Flagellum stramineous or light reddish yellow; body light reddish brown..... 7

7. Lateral ocellus distinctly behind posterior eye margin; head subquadrate, eye unusually small, face nearly as wide as eye length..... .....*Euphoriella foutsi* new species

   Lateral ocellus in line with posterior eye margin; head rectangular, much wider than long; face not nearly as wide as eye length .... *Euphoriella incerta* Ashmead

8. Flagellum reddish yellow; hind wing marginal cilia 0.5 to 0.6 times wing width; hind wing straplike; lateral ocellus behind posterior eye margin ..... *Euphoriella foutsi* new species

Flagellum dusky, sometimes lighter basally; otherwise not as described..... 9

9. Legs light yellow; flagellar segment I less than 2.0 times as long as wide, II and III about equal in length .... *Euphoriella sommermanae* Muesebeck

Legs reddish yellow; flagellar segment I about 2.0 times as long as wide, II longer than III ..... *Euphoriella solidaginis* new species

10. Tergite I entirely, finely, distinctly rugulose; body and appendages light chocolate brown ..... *Euphoriella pacifica* Muesebeck

Tergite I and color not as described 11

11. Flagellum and legs light yellow, face usually not as dark as frons or genae; hind tibia average length 0.54 mm ..... *Euphoriella pallidifacia* new species

Fagellum and legs testaceous or infuscated; face not paler than frons or genae; hind tibia not as long 12

12. Hind tibia average length 0.36 mm; mid and hind legs testaceous..... ..... *Euphoriella hyalopsocidis* new species

Hind tibia average length 0.31 mm; mid and hind legs deeply infuscated ..... *Euphoriella criddlei* new species

Descriptions of Nearctic *Euphoriella* Species

Euphoriella nixoni, New Species (Figures 4 and 17)

HOLOTYPE MALE. Length 2.2mm. Bicolorous. Head, basal 4 antennal segments and legs reddish yellow; flagellar segments III-XII dusky; thorax, propodeum, gaster reddish brown. Head rectangular, 1.5 times as wide as long; face between eyes slightly rounded, sparsely hairy, its width to length of scape + pedicel 1:1.0, to eye length 1:1.2, to eye width 1:0.9; temple as wide as eye; malar space about 0.3 times as wide as base of mandible, equal to pedicel width; flagellum 2.2 times as long as head width; length to width ratios of scape, pedicel, flagellar segments I-III 2.0, 1.7, 3.3, 2.6, 2.5:1.0; OOL 2.0 times as long as POL, OOL about as long as scape.

Mesonotum smooth, polished, few scattered hairs; prescutellar groove divided by 4 carinae; mesepisternum mat-like or finely granulose, depressed medially and finely sculptured; propodeum areolated though carinae obscured by dark color and reticulae, posterior face flat, vertical; stigma 2.1 times as long as wide; longest marginal cilia of hind wing about 0.5 times wing width. Tergite I almost 4.3 times as long as apical width, 0.7 times as long as hind tibia, quite smooth, somewhat broadened at spiracles.

TYPES: Holotype: ♂ UNITED STATES. *Maine,* Gilead, VII. 7, 1965 (L. J. Lipovsky). Type deposited in the U.S. National Museum, Washington (USNM No. 72152).

This species is recognized by color, large size, and the unusually long flagellar segment I. The female is unknown. It is named for G. E. J. Nixon of the Commonwealth Institute of Entomology, London in appreciation of his work on African Euphorinae.

Euphoriella kaladarensis, New Species (Figures 1-3, 12, 14, 18, 21)

HOLOTYPE MALE. Length 1.7 mm. Dark reddish brown. Scape, pedicel and flagellar segment I pale testaceous, remainder of flagellum dusky; mid and hind femur, tibia infuscated; tergite I and apex of gaster behind light reddish brown. Head 1.5 times as wide as long; face smooth, almost glabrous from above; face width to length of scape + pedicel 1:0.9, to length of eye 1:1.3; ;to width of eye 1:1.0; temple: eye 1:1.2; malar space = pedicel width, 0.5 times basal width of

TABLE I. Dimensions of *Euphoriella kaladarensis* n.sp. and *E. solidaginis* n. sp., and their separation. (Dimensions given in microscope ocular units, for antennal segments 1 unit = 0.0038 mm, for all others 1 unit = 0.0135 mm. Significance of differences between species by student's t-test shown as P <0.01 = **, P <0.05 = *, difference not significant = N.S., L = greatest length, W = greatest width)

		E. kaladarensis			*E. solidaginis*				
Sex	Structure	No.	Mean	S.E.	No.	Mean	S.E.	t	P
♂	Scape L	21	24.76	.293	9	22.11	.540	16.66	**
	Scape W	21	11.05	.563	9	11.71	.154	3.27	**
	Pedicel L	21	17.27	.207	9	16.00	.290	12.99	**
	Pedicel W	21	9.41	.093	9	9.25	.134	4.85	**
	Flagellar I L	21	16.75	.416	9	14.44	.503	12.48	**
	Flagellar I W	21	7.35	.154	9	6.67	.222	9.23	**
	Flagellar II L	21	19.70	.316	9	16.89	.351	20.58	**
	Flagellar II W	21	8.20	.145	9	7.33	.167	13.72	**
	Flagellar III L	21	16.85	.286	9	15.42	.236	12.54	**
	Flagellar III W	21	8.20	.145	9	7.67	.167	8.36	**
♀	Scape L				7	20.86	.886		
	Scape W				7	12.17	.408		
	Pedicel L				7	15.60	.216		
	Pedicel W				7	9.67	.314		
	Flagellar I L				7	12.57	.434		
	Flagellar I W				7	6.71	.247		
	Flagellar II L				7	14.14	.343		
	Flagellar II W				7	7.71	.154		
	Flagellar III L				7	13.43	.309		
	Flagellar III W				7	8.57	.453		
♂	Eye L	21	13.38	.146	9	12.56	.377	8.30	**
	Eye W	21	10.33	.129	9	10.22	.222	1.63	N.S.
	Face W	21	10.91	.145	9	10.89	.200	.24	N.S.
♀	Eye L				7	15.43	.369		
	Eye W				7	12.00	.218		
	Face W				7	9.14	.261		
♀, ♂	Stigma L	21	22.13	.408	16	21.56	.408	.409	**
	Stigma W	21	8.65	.160	16	8.94	.192	4.87	**
	Hind tibia L	21	29.38	.496	16	27.88	.378	9.78	**
	Tergite I L				16	14.95	.258		
	Hind wing W	21	13.91	.244	16	14.40	.388	4.57	**
	Cilia of hind wing	21	6.48	.125	16	6.13	.133	7.97	

mandible; flagellum 2.0 times as long as head width; length to width ratios of scape, pedicel, flagellar segments I-III 2.1, 1.8, 2.1, 2.3, 1.9:1.0; OOL:POL = 7:5, OOL not quite as long as scape; frons with a few scattered hairs otherwise glabrous, smooth, polished like genae and vertex. Mesonotum smooth, polished, prescutellar sulcus shallow, divided by a single median carina; mesepisternum glossy, rounded medially, smooth except finely sculptured for entire length below; hind wing rather narrow, longest marginal cilia 0.4 times wing width; stigma 2.4 times as long as wide; propodeum with pronounced declivity behind, sides finely reticulate, areolae of dorsal face distinct; hind tibia 0.41 mm long, spines at apex about as long as width of hind femur. Lenth of tergite I slightly more than 3.0 times apical width, about 0.7 times length of hind tibia, apex equal to hind femur width, widened distinctly at spiracles, dorsal face rugulo-striate.

TYPES: Holotype: ♂ CANADA. *Ontario,* Hastings Co. 8 miles west of Kaladar just south of highway no. 7, VII.1, 1969 beaten from *Diervilla Lonicera* Mill. (C. C. Loan). Type deposited in the Canadian National Collection, Ottawa (CNC No. 12676).

Paratypes: 3 ♀♀, 56 ♂♂. Of these, 3 ♀♀, 21 ♂♂ data as for holotype except collection dates VII.1-2, 1969; 18 ♂♂ data as for holotype except collec-

TABLE II. Dimensions of some characters of *Euphoriella sommermanae* Muesebeck and of *E. foutsi* n.sp. (Dimensions given in microscope ocular units, for antennal segments 1 unit = 0.0038 mm, for all others 1 unit = 0.0135 mm); L = greatest length, W = greatest width.

		E. sommermanae			*E. foutsi*		
Sex	Structure	No.	Mean	S.E.	No.	Mean	S.E.
♂	Scape L	5	20.80	1.78	8	24.50	.682
	Scape W	5	11.00	.629	8	11.63	.208
	Pedicel L	5	15.20	.973	8	15.63	.270
	Pedicel W	5	9.00	.446	8	9.00	.208
	Flagellar I L	5	13.00	1.23	8	14.25	.742
	Flagellar I W	5	6.60	.223	8	6.50	.332
	Flagellar II L	5	16.00	1.0	8	17.13	.516
	Flagellar II W	5	7.20	.388	8	7.38	.332
	Flagellar III L	5	15.20	.773	8	15.25	.403
	Flagellar III W	5	8.00	.317	8	7.63	.332
♀	Scape L	15	19.93	.016			
	Scape W	15	11.20	.168			
	Pedicel L	15	14.67	.207			
	Pedicel W	15	9.27	.176			
	Flagellar I L	15	10.93	.359			
	Flagellar I W	15	7.33	.120			
	Flagellar II L	15	12.80	.315			
	Flagellar II W	15	7.87	.195			
	Flagellar III L	15	12.93	.266			
	Flagellar III W	15	8.60	.195			
♂	Eye L	5	13.40	.589	8	12.10	.316
	Eye W	5	10.40	.589	8	9.40	.278
	Face W	5	11.00	.317	8	10.60	.278
♀	Eye L	15	15.79	.199			
	Eye W	15	11.61	.467			
	Face W	15	9.22	.890			
	Hind Tibia L	20	25.59	.369	8	27.30	.870
	Tergite I L	20	18.50	.184	8	19.28	.596

tion dates VII.6-7, 1970 and also beat from *Myrica Gale* L.; Dundas and Hamilton, Ontario, 17 ♂♂ VI.29, 1955 (O. Peck). 5 ♂♂ USNM, 5 ♂♂ BM, balance CNC.

Males. Variation of a number of important characters is given in Table I.

Females. As male except the legs are yellowish and except for sexual characters.

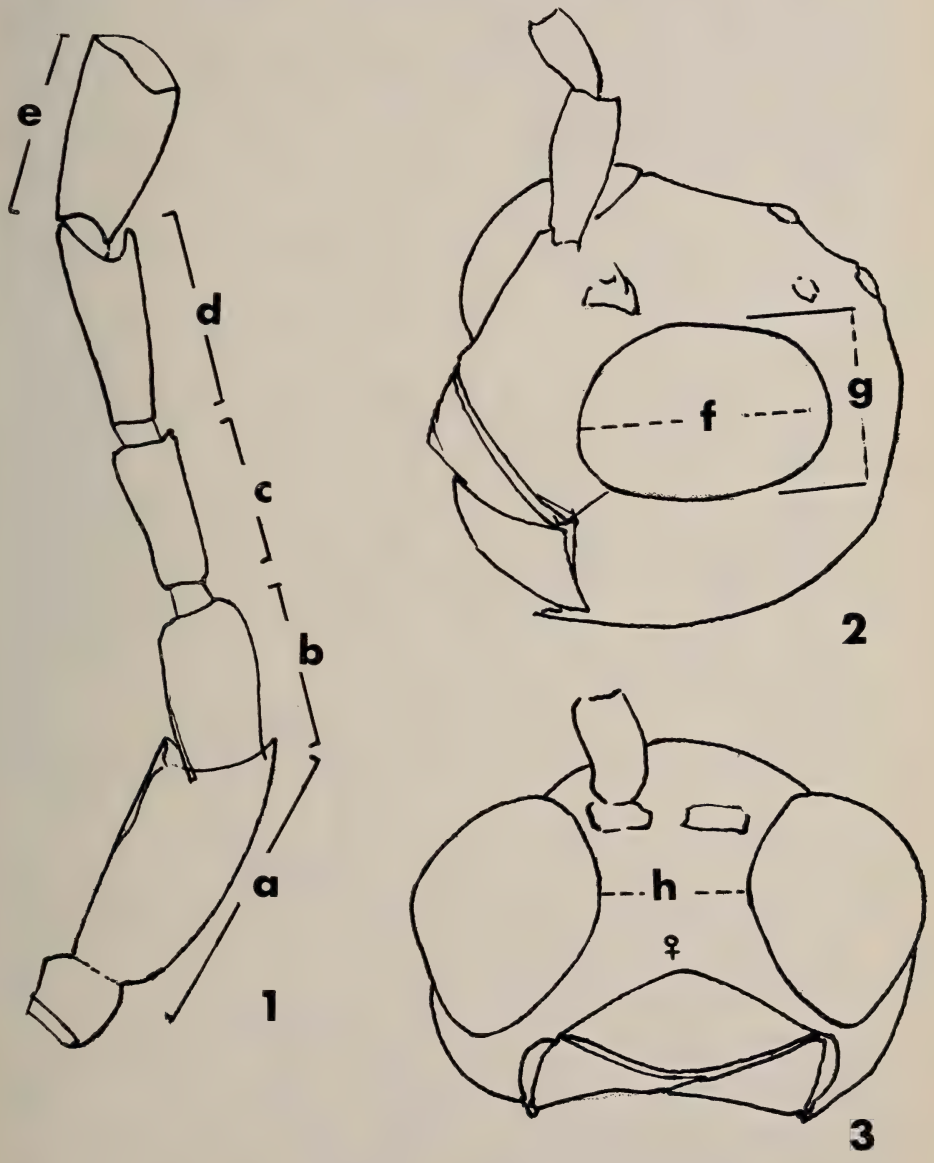
Superficially, *E. kaladarensis* closely resembles *solidaginis* new species but differs in numerous characters (Table I). Only a series of males were available to compare with *solidaginis* but the difference between means of measurements of antennal segments are significant at the $P<0.01$ level (t-test). *E. kaladarensis* is larger than *solidaginis* but its scape, stigma and hind wing are not as wide. There is also a temporal difference as *kaladarensis* is a mid-summer species whereas *solidaginis* flies in late spring and early summer. Specimens from the Hamilton-

TABLE III. Dimensions of *Euphoriella hyalopsocidis* n.sp. and *E. criddlei* n.sp., and their separation. Legend as in Table I.

		E. hyalopsocidis			*E. criddlei*				
Sex	Structure	No.	Mean	S.E.	No.	Mean	S.E.	t	P
♂	Scape L	10	29.20	1.19	6	25.17	1.33	5.81	**
	Scape W	10	13.90	.380	6	13.17	.706	2.51	*
	Pedicel L	10	17.20	.396	6	17.50	.707	1.02	N.S.
	Pedicel W	10	9.90	.182	6	10.67	.314	5.81	**
	Flagellar I L	10	18.80	.720	6	15.67	.147	9.61	**
	Flagellar I W	10	8.30	.047	6	7.83	.314	4.40	**
	Flagellar II L	10	21.70	.633	6	19.83	.122	6.54	**
	Flagellar II W	10	8.80	.047	6	8.50	.408	2.18	*
	Flagellar III L	10	18.80	.058	6	17.00	.078	49.14	**
	Flagellar III W	10	8.90	.180	6	8.83	.408	.44	N.S.
♀	Scape L	6	25.00	.816	6	23.83	.914	2.80	*
	Scape W	6	14.00	.633	6	13.33	.408	1.99	N.S.
	Pedicel L	6	17.33	.547	6	16.50	.058	3.37	**
	Pedicel W	6	10.50	.184	6	10.33	.257	1.20	N.S.
	Flagellar I L	6	14.33	.796	6	14.67	.796	.67	N.S.
	Flagellar I W	6	8.83	.408	6	8.00	0.0	4.55	**
	Flagellar II L	6	18.00	.776	6	16.67	.316	3.55	**
	Flagellar II W	6	9.50	.314	6	9.17	.184	2.03	N.S.
	Flagellar III L	6	15.33	.408	6	15.67	.316	1.47	N.S.
	Flagellar III W	6	10.50	.314	6	10.00	0.0	3.56	**
♂	Eye L	10	17.30	.236	6	14.67	.605	11.55	**
	Eye W	10	13.00	.298	6	11.50	.316	8.83	**
	Face W	10	13.80	.422	6	12.83	.703	6.42	**
♀	Eye I	6	19.98	.589	6	17.67	.547	6.74	**
	Eye W	6	14.00	.545	6	13.33	.408	2.20	N.S.
	Face W	6	12.00	.499	6	10.66	.483	4.31	**
♂, ♀	Stigma L	16	26.80	.527	12	24.82	.633	8.69	**
	Stigma W	16	11.00	.218	12	10.64	.316	3.44	**
	Hind tibia L	16	35.60	.448	12	31.36	1.23	12.29	**
	Tergite I L	16	24.07	.530	12	20.83	.523	15.49	**
	Hind wing W	16	18.87	.542	12	17.80	.930	3.68	**
	Cilia of Hind wing L	16	6.00	.138	12	6.40	.316	4.37	**

Dundas population are somewhat larger than those from Kaladar but color and size-ratios of body structures appeared to be the same. The time of field captures is also similar.

E. sommermanae Muesebeck resembles these species but is separable in females by leg color which is paler, and by the means of the body structures given in Table II.



FIGURES 1-3. Points of reference for measurement of some structures of *Euphoriella,* species illustrated *E. kaladarensis* new species. 1. Basal five antennal segments: a, scape; b, pedicel; c-e, flagellar segments I-III, respectively (female illustrated). 2. Eye: f, length; g, width (male illustrated). 3. Face: h, width (female illustrated).

Euphoriella solidaginis, New Species (Figures 7 and 8)

HOLOTYPE FEMALE. Length 1.6 mm. Dark reddish brown. Scape and pedicel light yellow, basal flagellar segments slightly darker and remainder of flagellum dusky; legs pale reddish yellow, hind femur and tibia very slightly darker; anterior half of gaster behind tergite I testaceous. Head 1.5 times as wide as long; face hairy, clypeal setae barely longer than scape; frons, lower genae, mandibles basally sparsely hairy; face width to length of scape + pedicel 1:1.2, to length of eye 1:1.9, to width of eye 1:1.3; temple not as wide as eye; flagellum 1.6 times head width; length to width ratios of scape, pedicel, flagellar segments I-III 1.8, 1.6, 1.9, 1.8, 1.5:1.0; malar space 0.3 times basal mandibular width, not as wide as pedicel; OOL:POL = 7:4, OOL = scape length. Prescutellar sulcus divided by 3 carinae; anterior and lateral margins of mesonotum thinly hairy; mesepisternum glossy, rounded medially with a granulose depression below; propodeum areolated, sides finely reticulate, length and posterior width at coxae about the same; stigma almost 3.0 times as long as wide; longest marginal cilia of hind wing almost 0.5 times wing width; hind tibia 0.41 mm long; hind femur width exceeds apical width of tergite I. Tergite I length about 3.0 times apical width, 0.7 times as long as hind tibia, dorsal face with fine, widely-spaced striae; gaster behind tergite I smooth, polished, 0.5 times as long as head, thorax and propodeum together.

TYPES. Holotype: ♀ CANADA. *Ontario*, Fuller, lat. 44° 24'N, long. 77° 25'W emerged V.13, 1969 from soil debris associated with *Solidago canadensis* L. (C. C. Loan and D. G. Reid). Type deposited in the Canadian National Collection, Ottawa (CNC No. 12675).

Paratypes: 6 ♀ ♀, 11 ♂ ♂, 3 ♀ ♀, 4 ♂ ♂, data as for holotype except emergence dates V.11-19, 1969; 3 ♀ ♀, 3 ♂ ♂ emerged V.16-29, 1970 from soil samples taken from *Solidago* plots on Concession 5, Thurlow Twp., 3 miles east of Foxboro, Ontario (on Mud-cat Lane); 4 ♂ ♂ swept V.31-VI.2, 1972 from *Solidago* at the latter locality. Of these 2 ♀ ♀, 2 ♂ ♂ USNM, 2 ♂ ♂ BM, balance CNC.

Males and females. Variation data are given in Table I.

This species is similar to *kaladarensis*. Separation characters are noted in the comments for *kaladarensis* and in the key to species.

Euphoriella sommermanae Muesebeck (Figures 5 and 6)

Euphoriella sommermanae Muesebeck. Proc. Entomol. Soc. Wash. 58: 148-149, 1956. Holotype female in the U.S. National Museum.

Muesebeck's description is supplemented by data given in Table II, which are based on a re-examination of the paratype series.

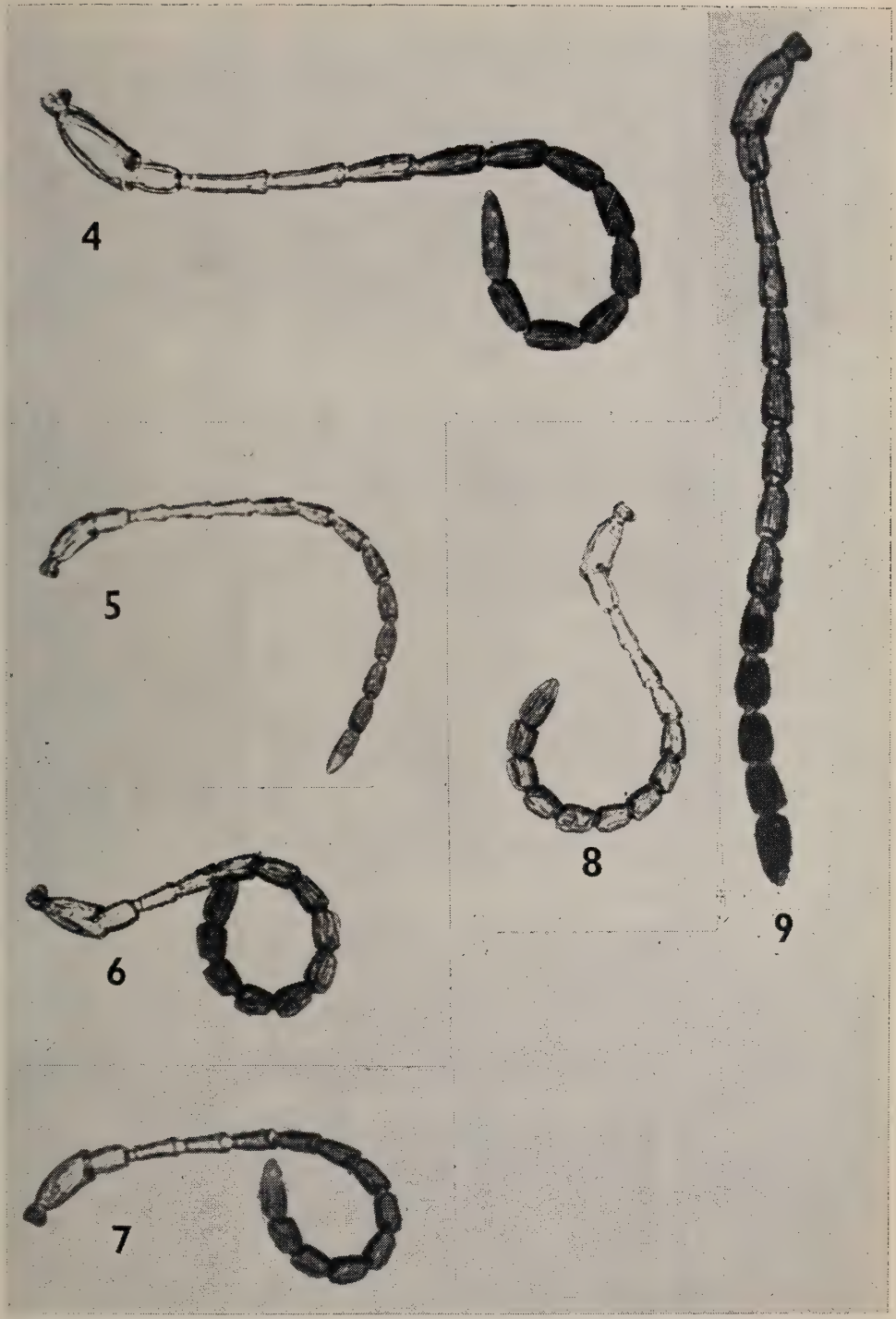
Euphoriella incerta (Ashmead)

Labeo incertus Ashmead. Entomol. Am. 3: 74, 1887.

Euphoriella incertus Ashmead. U.S. Natl. Mus. Proc. 23: 116, 1900.

Euphoriella incerta (Ashmead):Muesebeck, U.S. Dept. Agric. Misc. Publ. 241, 1936.

Holotype male in the U.S. National Museum.



FIGURES 4-9. Antennae of *Euphoriella* species. 4. *nixoni* n. sp. ♂. 5. *sommermanae* Muesebeck ♂. 6. *sommermanae* ♀. 7. *solidaginis* n. sp. ♂. 8. *solidaginis* ♀. 9. *pallidifacia* n. sp. ♀.

Muesebeck's (1936) description is supplemented as follows. Head 1.8 times as wide as long; face width to length of scape + pedicel 1:1.0, to length of eye 1:1.3, to width of eye 1:1.0; temple 0.7 times eye width; flagellar segments I-VII combined slightly more than 2.0 times as long as eye, segment I about as long as scape, II and III successively slightly shorter; pedicel 0.6 times scape length, not quite as wide; malar space = pedicel length or length of flagellar segment II; length of frons and width of temple subequal; ocellar triangle an acute angle at the median ocellus; OOL:POL = 8:5; lateral ocellus in line with posterior eye margin. Stigma 2.4 times as long as wide. Tergite I 3.3 times as long as apical width.

Ashmead's type is badly damaged: the left flagellum and segments VIII-XII of the right and all leg segments except the right hind trochanter and left hind coxa are missing. The wings adhere together and though the face appears glabrous, its pilosity is hidden by a varnish-like substance that also affixes the incomplete flagellum to the head.

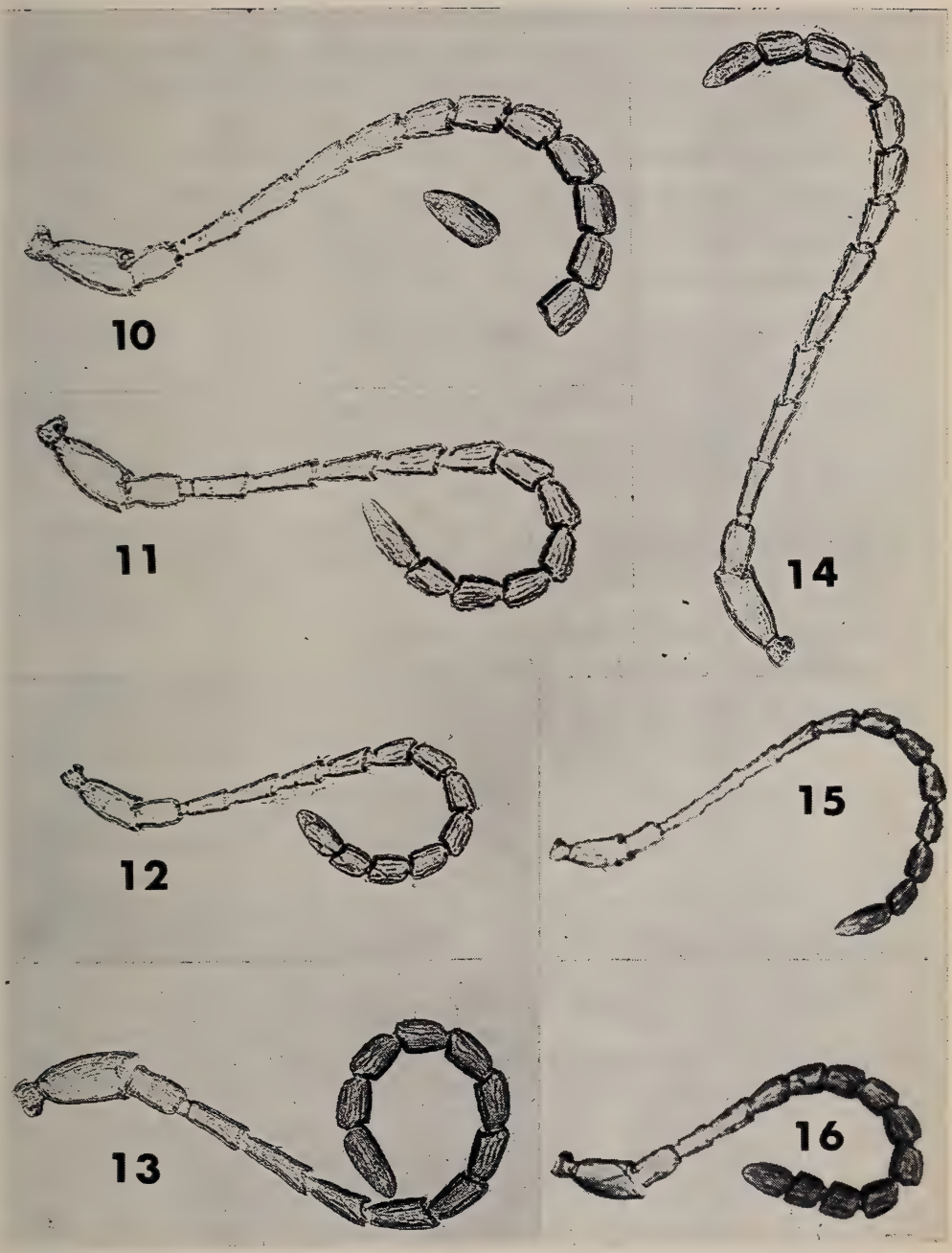
There are problems in the recognition of *incerta* that do not result primarily from the mutilated type. Variation in color and structure cannot be assessed because of the lack of a reliable series. Important characters of this species e.g. strap-like hind wing and pale appendages are also found in other material, which differs by sculpturing of tergite I, size of eye, and proportions of the basal antennal segments. Much of the latter material is described in this paper as *foutsi* new species. The possibility is recognized that when additional specimens and biological data become available, some specimens of this latter species may be found to belong to *incerta* or the species itself could be synonymized.

Euphoriella foutsi, New Species (Figure 15)

HOLOTYPE MALE. Length 1.4 mm. Light reddish brown. Scape, pedicel light yellowish; legs, flagellum light reddish yellow; hind tibia barely cinereous; gaster dark reddish brown. Head 1.4 times as wide as long; face with slight keel between antennal sockets, pilosity fine, puctulate, its width to length of eye 1:1.1, to width of eye 1:0.9, to temple with 1:0.9; length to width ratios of scape, pedicel, flagellar segments I-III 2.1, 1.7, 1.9, 2.3, 1.9:1.0; malar space = pedicel width, 0.5 times basal width of mandible; OOL 2.0 times as long as POL, OOL = scape length; frons, vertex, lower genae sparsely hairy. Mesepisternum smooth and polished medially, finely rugulose below tegulae; propodeum areolated, sides rugulose-reticulate, declivity of dorsal face slight, posterior face rather vertical; stigma 2.2 times as long as wide; hind wing unusually narrow, longest marginal cilia almost 0.6 times as long as wing width; hind tibia 0.34 mm long, spines at apex almost as long as width of hind femur. Tergite I 3.4 times as long as apical width, apex not as wide as hind femur, broadened somewhat at spiracles, finely striate dorsal surface.

TYPES. Holotype: ♂ UNITED STATES, *Maryland,* Cabin John, VIII.21, 1916 swept (R. M. Fouts). Type deposited in the U.S. National Museum, Washington, D.C. (USNM No. 72153).

Paratypes: 3 ♀ ♀, 8 ♂ ♂. *Iowa,* Sioux City, 1 ♀ VI.17, 1926 swept mixed vegetation south ravine (C. N. Ainslie); 1 ♀ V.22, 1935, 1 ♂ VI.4, 1935 same data as preceding paratype. *Maryland,* Cabin John, 1 ♂ VIII.21, 1916, 1 ♀ VII.1, 1917, 2 ♂ ♂ VIII.20-21, 1917 (R. M. Fouts); Takoma Pk., 1 ♂ no collection data (C. N. Ainslie); Glen Echo, 1 ♂ V.23, 1918, 2 ♂ ♂ VI.20, 1919 (R. M. Fouts). 1 ♀, 3 ♂ ♂ CNC, balance USNM.



FIGURES 10-16. Antennae of *Euphoriella* species. 10. *criddlei* n. sp. ♂. 11. *criddlei* ♀. 12. *kaladarensis* n. sp. ♀. 13. *hyalopsocidis* n. sp. ♂. 14. *kaladarensis* ♂. 15. *foutsi* n. sp. ♂. 16. *hyalopsocidis* ♀.

Males and females. Variation of some characters of male *foutsi* is listed in Table II. Except for sexual differences the female is similar to the male.

This new species is separable from the type of the genus, *incerta* by the more quadrate head, by the small eye which is more spherical than ovoid, and by the lateral ocellus being distinctly behind the eye.

Euphoriella pacifica Muesebeck

Euphoriella pacifica Muesebeck. U.S. Dept. Agric. Misc. Publ. 241, 1936.

Holotype female in the U.S. National Museum.

Muesebeck's description is supplemented as follows.

Face between eyes somewhat wider than temple, its width to length of scape + pedicel 1:0.9, to length of eye 1:1.4, to width of eye 1:1.0; malar space about as wide as scape and almost as wide as basal width of mandible; pedicel and flagellar segment I length subequal; pedicel, flagellar segment II longer than I or III; length to width ratios of scape, pedicel, flagellar segments I-III 1.8, 1.8, 2.0, 1.8, 1.4:1.0; anterior margin of lateral ocellus in line with posterior eye margin. Hind tibia 0.28 mm long.

E. pacifica is unique as shown by the characters noted in the species key. Further, it is the only species with the face of the female as wide as the eye.

Euphoriella pallidifacia, New Species (Figure 9)

HOLOTYPE FEMALE. Length 2.0 mm. Piceous. Antennae and legs light reddish yellow; head paler than thorax; face paler than frons or genae. Head 1.6 times as wide as long; face somewhat shagreened, in side view flat, vertical, moderately hairy, its width to length of scape + pedicel 1:0.7, to length of eye 1:1.7, to eye width 1:1.4; temple not as wide as eye, only slightly wider than face; flagellum length 1.9 times head width; length to width ratios of scape, pedicel, flagellar segments I-III 1.5, 1.7, 2.0, 2.1, 1.8:1.0; malar space less than half width of base of pedicel; OOL:POL = 9:7, OOL about as long as scape; lateral ocellus distinctly behind posterior eye margin. Mesonotum finely granulose posteriorly; prescutellar sulcus divided by a single medial carina; mesepisternum (except posterio-medially) indistinctly marked with fine striae and punctulation; propodeum areolated, sides finely reticulate, declivity of dorsal face not pronounced and not as long as depth of posterior face; hind tibia 0.54 mm long, length of apical spines to width of hind femur 5:7. Tergite I 3.4 times as long as its posterior width, 0.6 times length of hind tibia, apical margin about as wide as hind femur, somewhat broadened at spiracles, dorsal face with 4 distinct but fine striae and rugulose medially, hairy near spiracles and at apical margin.

TYPES. Holotype: ♀ CANADA. *Quebec,* Old Chelsea, V.25, 1960 (J. R. Vockeroth). Type deposited in the Canadian National Collection, Ottawa (CNC No. 12677).

Paratypes: 2 ♀ ♀, 1 ♂. *Quebec,* Meach Lake, 1 ♀ VI.8, 1962 (S. M. Clark); 1 ♀ V.27, 1960, data as for holotype but captured summit King Mt., 1150'; Gatineau Pk. at Champlain Look-out, 1 ♂ VI.1, 1965 (J. R. Vockeroth). All CNC.

E. pallidifacia is distinguished by a relatively wide hind wing and by the pale antennae and yellowish legs. The face, frons and genae are not as dark as the

thorax, and the lateral ocellus is behind the posterior eye margin. This combination of characters facilitates separation from other species seen to date.

The head of one of the paratype females is light reddish brown and only slightly darker than the face.

Euphoriella hyalopsocidis, New Species (Figures 13 and 16)

HOLOTYPE FEMALE. Length 2.1 mm. Reddish black. Flagellum dusky except light testaceous basally similar to fore and mid legs; hind femur, tibia darker testaceous. Head 1.3 times as wide as long; face in side view slightly rounded, covered by moderately dense hair, its width to length of scape + pedicel 1:1.0, to length of eye 1:1.7, to eye width 1:1.4; malar space = pedicel width, 0.6 times basal mandibular width; flagellum 1.6 times as long as head width; length to width ratios of scape, pedicel, flagellar segments I-III 2.1. 1.5, 1.9, 1.9, 1.5:1.0; temple 0.8 times as wide as eye; OOL:POL = 7:5, OOL not quite as long as scape; vertex, frons, genae smooth, glossy, predominantly glabrous. Prescutellar depression divided by a single medial carina; ventral half of mesepisternum finely rugulose; propodeum about as wide as long, dorsal face rather short and not as long as posterior face, areolation obscured by dark color, lateral reticulae, rugulosity; stigma 2.5 times as long as wide; longest marginal cilia of hind wing 0.3 times as long as wing width; hind tibia 0.46 mm long. Tergite I slightly more than 3.0 times as long as apical width, 0.7 times length of hind tibia, apical margin about as wide as hind femur, widened at spiracles, dorsal face longitudinally striate, in lateral view rounded but not arched.

TYPES. Holotype: ♀ CANADA. *Ontario,* 3 miles west of Belleville on Canadian Pacific Railway right-of-way, VII.8, 1970, captured on weathered, vertical fence-posts (C. C. Loan). Type deposited in the Canadian National Collection, Ottawa (CNC No. 12673).

Paratypes: 4 ♀ ♀, 10 ♂ ♂, data as for holotype except captured VII.8-10, 1970, and 1 ♀ emerged IX.2, 1964, reared from nymph of *Hyalopsocus striatus* (Walker) collected at the type locality. 2 ♀ ♀, 2 ♂ ♂. USNM, 2 ♂ ♂ BM, balance CNC.

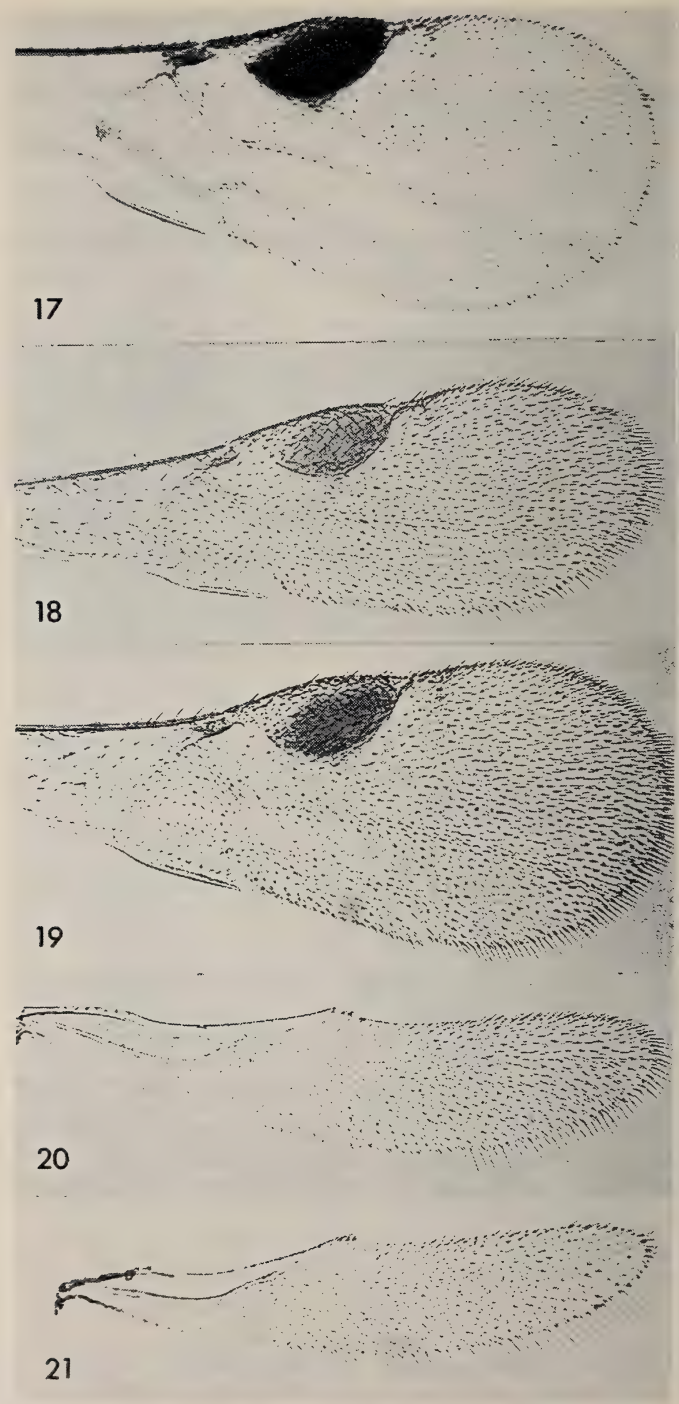
Males and females. Except for sexual characters the male is similar to the female. The scape of the male is longer ($P<0.01$), but equal in width. Variation of some structural characters for each sex is given in Table III.

Host: Associated by rearing from *Hyalopsocus striatus* (Walker).

E. hyalopsocidis is the largest of the species characterized by a relatively wide hind wing. Of these, the antennae and legs of *pallidifacia* are light yellowish and the tergite 1 is predominantly rugulose; *criddlei* new species is piceous rather than dark brown and its legs are deeply infuscated. Further differences, between *hyalopsocidis* and *criddlei* are listed in Table III.

Euphoriella criddlei, New Species (Figures 10, 11, 19 and 20)

HOLOTYPE FEMALE. Length 1.6 mm. Black. Flagellum basally, scape, pedicel, tarsal segments, fore tibia light testaceous; flagellum apically reddish brown; fore femur, mid and hind femur, tibia infuscated. Head subquatrate, 1.3 times as wide as long; face in side view evenly rounded, sparsely hairy, in dorsal view quite glabrous with very fine, indefinite sculpture; face width to length of



FIGURES 17-21. Wings of *Euphoriella* species. 17. Front wing *nixoni*. 18. Front wing *kaladarensis*. 19. Front wing *criddlei*. 20. Hind wing *criddlei*. 21. Hind wing *kaladarensis*.

scape + pedicel 1:1.0, to length of eye 1:1.8, to eye width 1:1.3; temple as wide as face; basal width of mandible 2.0 times pedicel width, somewhat less than 2.0 times malar space; flagellum 1.7 times as long as head width; length to width ratios of scape, pedicel, flagellar segments I-III 1.9, 1.6, 1.6, 1.9, 1.5:1.0; temple = eye width; OOL:POL = 8.6, OOL about = scape length; vertex, frons and genae, polished, smooth and relatively glabrous. Mesonotum glossy, few hairs on lateral margins; prescutellar groove narrow, shallow divided by a single medial carina; mesepisternum slightly foveolate near tegulae, fine striae and pitting below raised medial area; propodeum indistinctly areolated, moderately declivous behind; stigma 2.5 times as long as wing width; hind tibia 0.34 mm long. Tergite I 3.3 times as long as apical margin. 0.8 times length of hind tibia, apical width about equal to width of hind femur, in side view broadly convex, dorsal face rugulose-striate, somewhat widened at spiracles.

TYPES. Holotype: ♀ CANADA. *Ontario*, 3 miles west of Belleville in an abandoned apple orchard a short distance south of the Canadian National Railways right-of-way, VI.3, 1970, beat from foliage of mature apple trees (C. C. Loan). Type deposited in the Canadian National Collection, Ottawa (CNC No. 12674).

Paratypes: 5 ♀ ♀, 6 ♂ ♂, data as for holotype except collection dates VI.3-5, 1970. E ♀, 1 ♂ USNM, balance CNC.

Males and females. Except for sexual characters the male is similar to the female. The length of the scape is not significantly different between the sexes. Variation of some taxonomic characters is summarized in Table III.

This species is named for the Canadian naturalist Norman Criddle (1875-1933).

Acknowledgements

For the generous loan of types and other material we thank C. F. W. Muesebeck, Department of Entomology, Smithsonian Institution, Washington, D.C., Paul Marsh, Systematic Entomology Laboratory, U.S. Department of Agriculture, Washington, D.C., and W. R. M. Mason, Entomology Research Institute, Canada Department of Agriculture, Ottawa. We also appreciate criticisms of the typescript by these systematists. The permission of J. F. Perkins, British Museum (Nat. Hist.), London, to examine type material is gratefully acknowledged. We thank Sherwood Miller, Research Station, Canada Department of Agriculture, Smithfield, Ontario for computer assistance.

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AN EVALUATION OF SOME OF THE FACTORS THAT MAY CONTRIBUTE TO PROLIFERATION OF BRACONID PARASITES

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Abstract

This paper presents the view that the smaller and more weakly sclerotized braconid groups, such as Aphidiinae, may be more competitive and more highly evolved than the larger and more heavily sclerotized groups such as Doryctinae. Factors which may contribute to such a classification are evaluated and a phylogenetic tree of Braconidae incorporating these factors is proposed.

* * * * * *

Within the cuticle of the host, such as the aphid or caterpillar (Figs. 12-14), there is a limited amount of energy resource available for structuring the parasite(s). The proportional expenditure of energy on various parts of the anatomy of the parasite, could influence its degree of biological success. A structural advantage could bring about an increase in the population size of one species, resulting in a depletion of resources, and a proportional population decrease in the less efficient species. Thus, one may anticipate a perpetual emergence of parasite populations, achieving ever higher levels of efficiency, and competing with or subduing population levels of less efficient forms.

The following are some of the structural alternatives which have arisen in adult braconids, together with notes on their possible biological advantages.

1. **Morphological excellence of the adult** to provide the highest level of protection against predation, dessication, infection and other environmental hazards, thereby prolonging life and facilitating assimilation of more food for increased fecundity and viability.

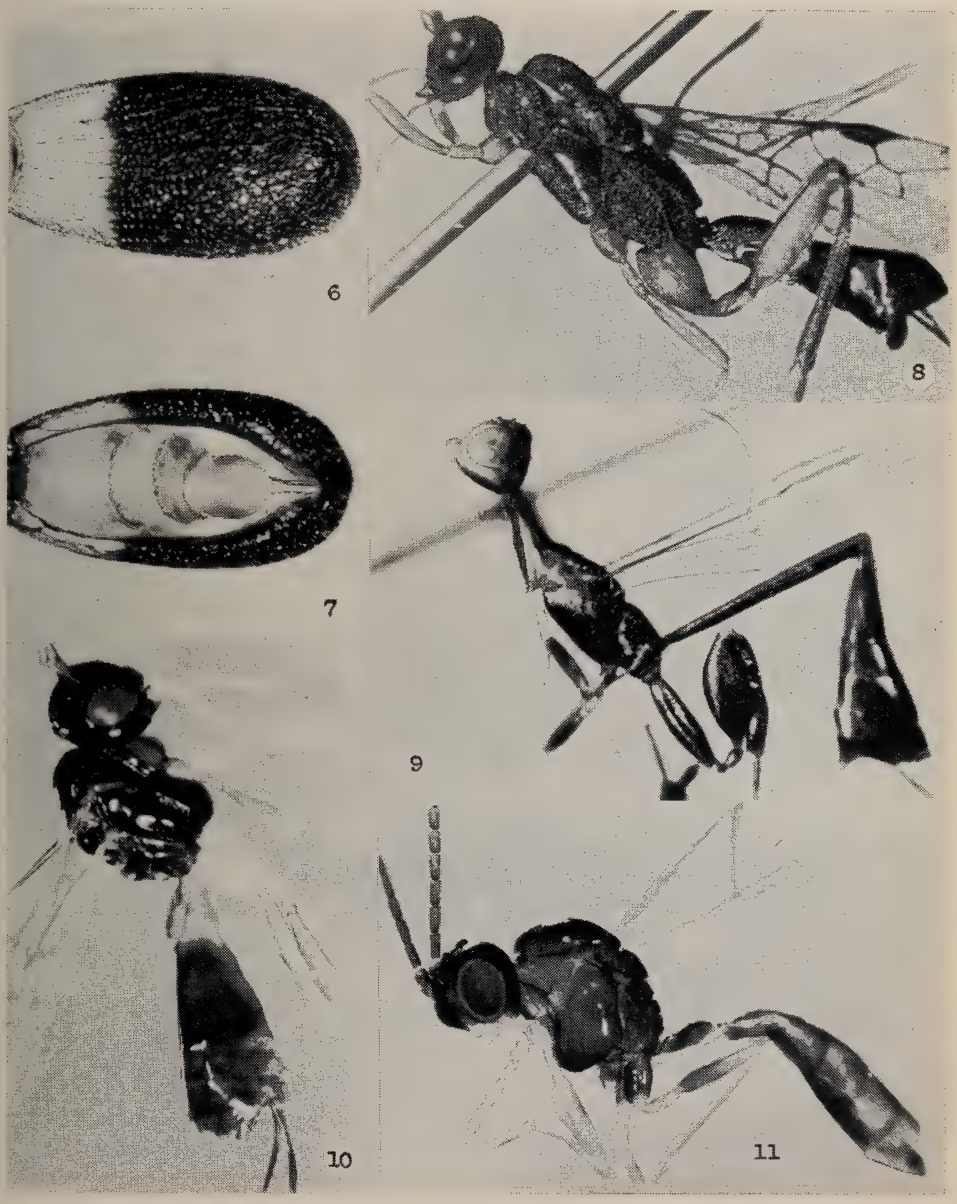
To evaluate the biological merits of such an alternative, the exoskeletal structure of the abdomen is taken into account. Fig. 1 shows an abdomen with 7 fairly heavily sclerotized abdominal tergites. Fig. 2 shows terminal abdominal tergites V-VII mostly retracted beneath tergite IV and greatly reduced. One might estimate that the savings of energy resources accrued from tergites V-VII would account for the increased sclerotization of tergites I-IV which in turn might provide a higher measure of protection. Fig. 3 shows tergites IV-VII strongly reduced and retracted beneath enlarged tergites I-III. In Fig. 4 the dorsal aspect of the abdomen is composed of tergites I-III fused together with transverse sulci showing the points of fusion of the tergites. Fig. 5 shows the three tergites ankylosed into one inflexible and heavily sclerotized carapace that encloses all but the ventral aspect of the abdomen. Figs. 6 and 7 show dorsal and ventral views of the abdomen. Fig. 7 shows abdominal apparatus almost completely enclosed within the carapace, with the ventral aspect open to permit expansion of sexual products and oviposition. This type of abdomen exhibits the highest structural excellence of the abdominal exoskeleton in braconids and adults with this kind of abdomen have been observed to live for several months. It is interesting to note that at least

half a dozen unrelated parasitic groups have arisen independently, bearing this type of abdomen, indicating a positive selective advantage in the development of this type of abdominal exoskeleton.

Bearing such structural advantage, one might anticipate that numerous various sized parasites would successfully compete for, and dominate diverse ecological niches. But this does not appear to be the case. Most of the groups in which this

FIGURES 1-5. 1, *Rogas* abdomen x 24. 2, *Bucculatriplex* abdomen x 48. 3, *Calyptus* x 48. 4, *Triaspis* x 48. 5, *Ascogaster* x 24.

type of abdomen has arisen are quite rare, and even Cheloninae — one of the largest of these groups — has only a moderate number of species, and occurs at the rate of 1:25 braconids normally collected, while another group, Microgasterinae (Figs. 14-16) with a weakly sclerotized abdomen has a very large number of scarcely separable species and occurs at the rate of 1:3 braconids normally collected.



FIGURES 6-11. 6, *Microchelonus* abdomen (dorsal view) x 48. 7, *Microchelonus* abdomen (ventral view) x 48. 8, *Helcon* x 10. 9, Stephanidae x 6. 10, *Orthostigma* x 40. 11, *Aphidius* x 48.

Another consideration that arises from such a population and species comparison is: if in highly modified and compact forms there does not appear to be any distinct biological advantage contributing to population dominance or species proliferation, then heavily sclerotized forms that are not so compactly and economically structured would have even less biological advantage. Fig. 8 shows Helconinae — one of the larger parasitic groups in Braconidae. The subfamily Helconinae has only a few species and occurs at the rate of 1:97 braconids

FIGURES 12-16. 12, Mummified aphid x 40. 13, Caterpillar with numerous exit holes and *Rogas* x 6. 14, Cutworm larva with numerous cocoons and *Apanteles* x 6. 15, *Apanteles* x 40. 16, *Microgaster* x 24.

normally collected. Fig. 9 shows a member of Stephanidae, a family which does not closely resemble any other parasitic group since all of its transitional forms have become extinct. Members in this family are presently quite uncommon and are rarely collected. It may be pointed out that members of Helconinae and Stephanidae are parasitic on hosts that usually live beneath the bark in shrubs and trees — areas that cannot be probed by smaller parasites; thus it may be that these niches serve as refugia for the larger and more heavily sclerotized, but probably less competitive parasitic forms.

2. **Maximal fecundity and viability in the shortest interval of time** to minimize losses due to prolonged exposure of the adult to environmental hazards.

Reduction of sclerotization of the adult (Figs. 10, 11) permits the energy resources gained from the host (Figs. 12-14) to be used in producing a large and viable egg load in the shortest interval of time. Reduced longevity of the adult compensated by increased longevity of the larva, for assimilation of nutrient essential for the development of the egg load, could have some survival advantage. The larvae of endoparasites are concealed within the body cavity of their host, thus they are not directly exposed to environmental hazards; in the case of ectoparasites, the hosts themselves together with the parasite larvae are usually concealed within plant tissue and are thereby also protected. The propensities of such a biological scheme are further borne out when one examines the frail and short-lived adults of such prolific groups as Cecidomyiidae (Diptera). It appears that longevity of the larva is extended, during the period the larva is embedded in the tissue of the host, to assimilate and store sufficient nutrient to develop the egg load in the adult female without further intake of nutrient during the adult period. Thus, it may be that evolution encompasses reduction of the stature and excellence of the adult to a more or less weakly sclerotized egg carrying basket whose principal role is to fertilize and implant the eggs into the host in the shortest possible time.

Adults with weakly sclerotized abdomens — two of which are shown in Figs. 10 and 11 — are found in numerous braconid groups. At the same time, these groups have more highly evolved wing venational patterns which indicate that they occupy higher phylogenetic positions.

In some braconids, egg proliferation and development have become highly specialized. Members in the subfamily Macrocentrinae are polyembryonic; the egg divides again and again and up to 150 embryos may be produced from a single egg. In other advanced braconid groups, the size of the parasite egg is greatly reduced, requiring less nutrient from the parasite for the development of such an egg, thereby facilitating formation of more eggs from a given amount of energy resource. The minute egg oviposited by the parasite into the host draws upon the nutrient of the host, and may increase over 2000 times in size before it becomes fully developed.

3. **Energy resources of host divided to increase number of individuals** (to minimize risk involved in carrying all the eggs in one basket) thereby greatly reducing the size of the individual.

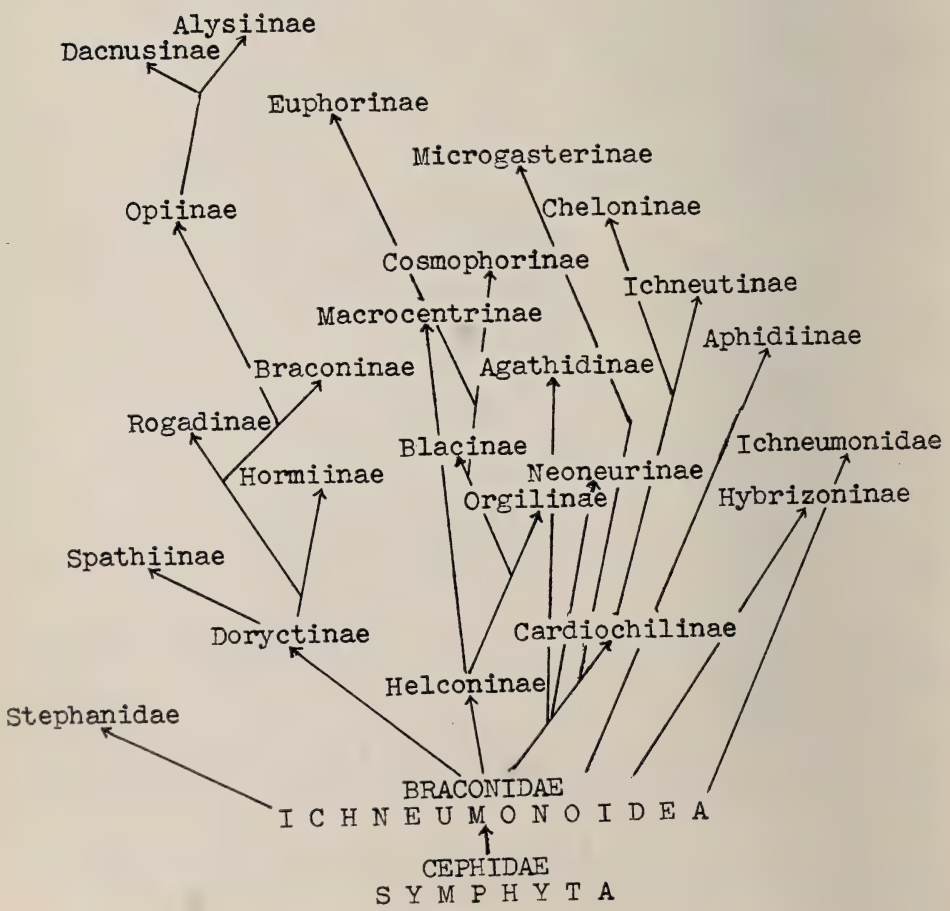
Fig. 13 shows part of a caterpillar riddled with holes from which numerous minute adults emerged; one of the adult *Rogas* parasites is shown. Fig. 14 shows part of a cutworm with numerous cocoons (50-100) spun by the parasite larvae that emerged from the cutworm. An adult *Apanteles* that emerged from one of the cocoons is also shown. Fig. 15 shows an adult *Apanteles* which in many cases is able to inject over 100 eggs into the host in a short time. Fig. 16 shows a *Microgaster* with abdominal tergites weakly sclerotized.

Microgasterinae has numerous scarcely distinguishable species that have branched out extensively to occupy many diverse ecological niches, and occurs at the rate of 1:3 braconids normally collected. This subfamily is undoubtedly the most prolific group in Braconidae.

Similar situations of numerous parasites emerging from a single host are also found in another highly evolved group — Chalcidoidea. It may be that the biological success, or advantage in population density and species proliferation, is more likely due to reproductive numerical superiority rather than to the "excellence of the adult." It may also be that these numerous minute and frail individuals have some advantage in competing for resources with individuals that are more elaborately structured and may be undermining their resources to the point of progressively effecting their extinction.

Assuming that a phylogenetic trend is influenced by such factors as outlined above, the following "phylogenetic tree" based on such considerations is proposed.

PHYLOGENETIC TREE OF BRACONIDAE



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WASPS (VESPIDAE) POLLINATING HELLEBORINE, *EPIPACTIS HELLEBORINE* (L.) CRANTZ, AT OWEN SOUND, ONTARIO

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Abstract

Four species of wasps, *Polistes fuscatus, Vespula arenaria, consobrina* and *vidua,* were found in August, 1970 at Owen Sound, Ontario feeding at flowers of helleborine, *Epipactis helleborine.* Most of them carried on their heads the pollinia of the plant. Some were found dead in spider webs on the flowers. Two spiders, *Enoplognatha ovata,* were found in the webs.

* * * * * *

The helleborine, *Epipactis helleborine* (L.) Crantz, is a European orchid which was introduced into North America, first being noted at Syracuse in 1879. It was found first in Ontario in 1890 at Lambton Mills near Toronto and since then has spread over much of the southern part of the province, particularly where limestone bedrock is present (Soper and Garay, 1954). It reached the Bruce Peninsula by 1952 where the plants produce a healthy growth on the limestone of the Niagara Escarpment.

The structure of the flower of helleborine and its pollination have been studied by various authors who note that the pollinating agents are almost exclusively wasps of the family Vespidae (Darwin, 1877; Knuth, 1909; Meeuse, 1961). A wasp lands on the labellum, the lower petal, and laps at the nectar collected in it. As the lapping proceeds, the head of the wasp moves forward and upward so that it rubs against the stigma of the flower. Pollen on the wasp's head, brought from another flower, is rubbed off on the stigma, thus ensuring cross-pollination. Further

movement of the wasp brings the head in contact with the sticky rostellum, part of the anther of the flower. The rostellum sticks to the head of the wasp. The wasp, having finished lapping nectar, backs out of the flower, taking with it the rostellum and the pollinia or pollen sacs which are attached to the rostellum. The two pollinia dry rapidly and in so doing bend down over the front of the wasp's head so that their pollen is easily rubbed off on the stigma of the next flower visited.

Knuth (1909) points out that in Europe pollination of helleborine is almost entirely by wasps and lists four species involved. Meeuse (1961) says that in Holland three wild orchids in the genus *Epipactis* are always referred to as "wasp orchids". Darwin (1877) concluded that "If wasps were to become extinct in any district, so probably would the *Epipactis latifolia*". The name *E. latifolia* is synonymous with *E. helleborine* (Fernald, 1950).

In August, 1970 an opportunity was taken of studying the pollination of helleborine at three sites in the vicinity of the city of Owen Sound which is on Owen Sound, a bay of Georgian Bay in Ontario: 1. open woods at a cottage on the east shore of Owen Sound three miles north of the village of Leith which is seven miles north of Owen Sound; 2. open woods at Inglis Falls, two miles south of Owen Sound where the Sydenham River flows over the Niagara Escarpment into Owen Sound; 3. open woods at Jones Falls two miles west of Owen Sound where the Pottawatomi River flows over the escarpment into Owen Sound. At each site about two hours were spent scanning the plants of helleborine and watching the activities of wasps. The weather was warm and sunny with no wind moving the plants. When a wasp was found at a flower it was captured and examined for the presence of pollinia. The wasps were identified with keys in Bequaert (1940) and Miller (1961). The pinned specimens are deposited in the collection of the Department of Zoology, University of Western Ontario. The genera *Polistes* and *Vespula* were represented. The following wasps were collected (*—indicates that the wasp had pollinia attached to the head):—

Leith, August 2:

1. *V. arenaria,* worker (*)—flying near flowers
2. *V. arenaria,* worker (*)—feeding at flowers
3. *V. arenaria,* worker (*)—flying near plant
4. *V. consobrina,* worker (*)—feeding at flowers

Inglis Falls, August 2:

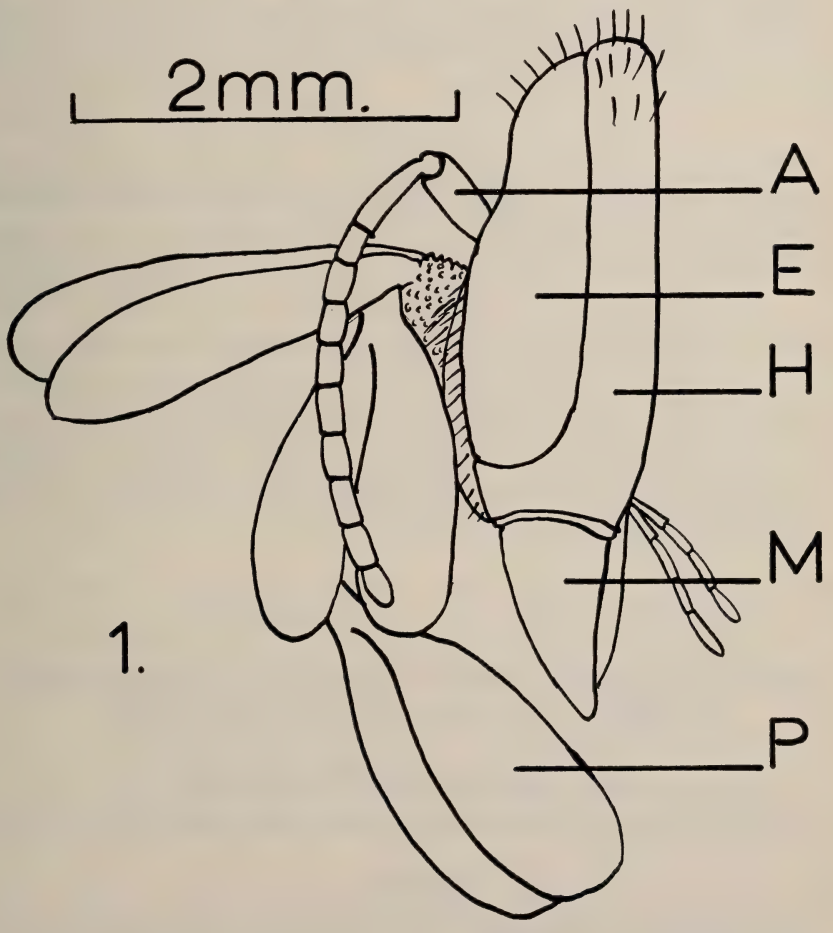
5. *P. fuscatus,* worker—feeding in flower
6. *V. consobrina,* male—feeding in flowers
7. *V. arenaria,* worker (*)—dead in web on flower
8. *V. arenaria,* male—feeding in flowers
9. *V. arenaria,* worker (*)—dead in web on flower
10. *V. arenaria,* worker (*)—dead in web on flower
11. *V. arenaria,* male—dead in web on flower
12. *V. arenaria,* worker—dead in web on flower

Jones Falls, August 3:

13. *V. vidua,* worker (*)—feeding in flowers
14. *V. arenaria,* male (*)—feeding in flowers
15. *V. consobrina,* worker—dead in web on flower

Two wasps were flying near the plants, seven were feeding in the flowers and six were dead in spider webs on the flowers. Two spiders, *Enoplognatha ovata* (Clerck), were found, one in the web which held wasp No. 7 and one in the web which held the two wasps, Nos. 9 and 10 in adjacent flowers. The genus *Enoplognatha* includes spiders which are commonly found on plants (Comstock, 1948). The two *E. ovata* were identified by Dr. C. D. Dondale, Entomology Research Institute, Department of Agriculture, and are preserved in the collection of the Department of Zoology, University of Western Ontario.

The pollinia were stuck to the hairs of the head on the lower frons and the clypeus. In some cases they were crushed against the head and formed an amorphous mass of farinaceous pollen grains. In others the pollinia retained their sac-like form. As many as three pairs of pollinia were found attached to the head. Wasp No. 13, *V. vidua* (Fig. 1), had a mass of pollen crushed against the head and three intact pairs of pollinia attached beyond this to one another, thus indicating that the wasp had recently visited at least four flowers.



Lateral view of head of *Vespula vidua* bearing three pairs of pollinia A — antenna; E — compound eye; H — head capsule; M — mandible; P — pollinium.

No insects other than wasps were seen visiting the flowers. Only wasp of the genus *Polistes,* a *P. fuscatus* (Fabr.), was found at a flower. This species is common in eastern North America (Bequaert, 1940). All the other wasps were of the genus *Vespula.* The commonest was *V. arenaria* (Fabr.) which Miller (1961) reports to be one of the commonest wasps in North America, distributed across the continent in the Boreal region. *V. consobrina* (Saussure) is a Nearctic species distributed across North America (Miller, 1961). *V. vidua* (Saussure) is in the Transition and Upper Austral zones of eastern North America, and at Owen Sound is at the northern limit of its range (Miller, 1961).

The known pollinators of helleborine reported in Europe by Darwin (1877) and Knuth (1909) are *V. sylvestris* Scop., *rufa. L., vulgaris* (L.) and *austriaca* (Panzer). The first two of these are European only while the latter two occur also in North America (Miller, 1961). Miller (1961) records sixteen species of *Vespula* in North America, including the three species found at Owen Sound. These three together are widely distributed in North America and if responsible alone for pollinating helleborine could account for the spread of the plant. However, it is likely that all sixteen species are capable of pollinating this plant. Thus any restriction of the spread of helleborine in North America would be due to other factors than the evident "monopoly" which wasps have in the pollination of this orchid.

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A KEY TO SAWFLY LARVAE FEEDING ON THE FOLIAGE OF SPRUCE AND BALSAM FIR IN ONTARIO

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Abstract

An illustrated key to 14 species of sawfly larvae on spruce and balsam fir in Ontario is presented.

* * * * * *

Introduction

Since Brown (1941) presented a key to six species of sawfly larvae on spruce, additional information has become available:
Pristiphora lena Kincaid has been added to the list of tenthredinids (Lindquist 1959); and Middlekauff (1958) and Eidt (1969) have increased our knowledge of the pamphiliids although larval identification is still uncertain in this group. Fourteen species of sawflies are treated in the following key from information drawn from the literature and studies of larvae collected in Ontario by the Forest Insect and Disease Survey. Species on balsam fir were included since this tree is closely linked ecologically to spruce. Yuasa's (1922) work on Tenthredinoidea larvae was consulted frequently during the construction of the key. The number and position of setae on abdominal segments are variable and can be used only as a general guide for identification purposes.

Key to Larvae

1. Larvapods present on many abdominal segments; antenna with three or four segments (Figs. 1 to 3); subanal appendages absent. 2

   Larvapods absent; antenna with seven segments (Fig. 4); subanal appendages present (Fig. 6). (Pamphiliidae). 6

2. Well-developed larvapods on abdominal segments 2 to 8 and 10; antenna 3-segmented, the third segment elongate (Figs. 2 and 3). 5

   Well-developed larvapods on abdominal segments 2 to 7 and 10 (a reduced pair may be present on 8); antenna 4-segmented and mainly flat (Fig. 1); on spruce only. 3

3. Head yellowish to orange or black; spine-bearing suprapedal lobe on abdominal segments dark or with some dark pigment (Figs. 7 and 9). 4

   Head pale green in living larva with a dark patch above the ocellus and along the anterior lateral curve of the head; no dark pigment on suprapedal lobe of abdominal segments (Fig. 8); body green to blue-green with a wide white band in the supraspiracular area and a less distinct addorsal pale line. June to August. ..... *Pikonema dimmockii* (Cress.)

4. Larva with waxy appearance, ground colour variable but usually olive green; paired, narrow, middorsal dark lines and wide dark subdorsal and subspiracular bands (Fig. 7); midventral eversible glands, and larvapod on abdominal segment 8, absent; head yellow-orange to black. Mature larva about 21 mm long. June to October . ..... *Pikonema alaskensis* (Roh.)

   Larva not waxy, ground colour olive green; middorsal line narrow, dark, subdorsal line wide, dark, subspiracular dark line absent (Fig. 9); midventral eversible glands present; reduced larvapods on abdominal segment 8; head yellowish in final stage, black earlier. Mature larva about 11 mm long. June and July. ..... *Pristiphora lena* Kincaid

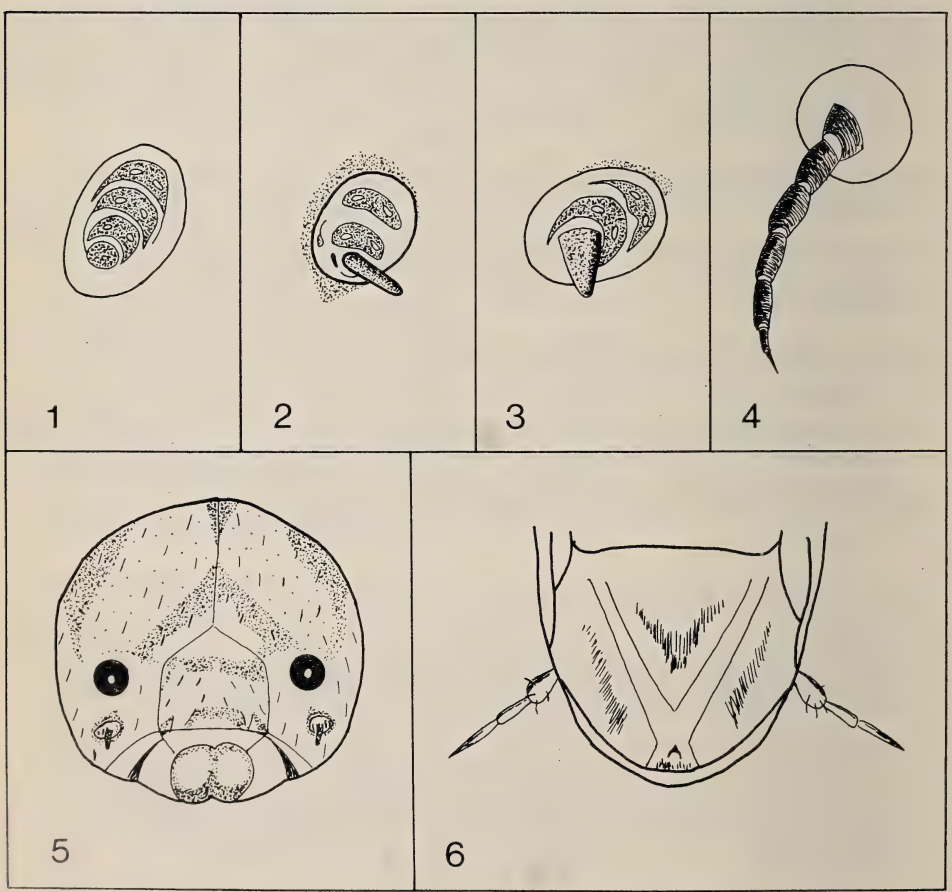
5. Head yellowish with a dark brown band along the coronal suture branched above the frons towards the ocelli, a row of markings across the frons between the ocelli, and with laterodorsal markings (Fig. 5); body dark green, with white lines except in final instar (Fig. 10). On spruce from June to

October (bivoltine). A European species (Lorenz and Kraus 1957). .... *Diprion hercyniae* (Htg.)

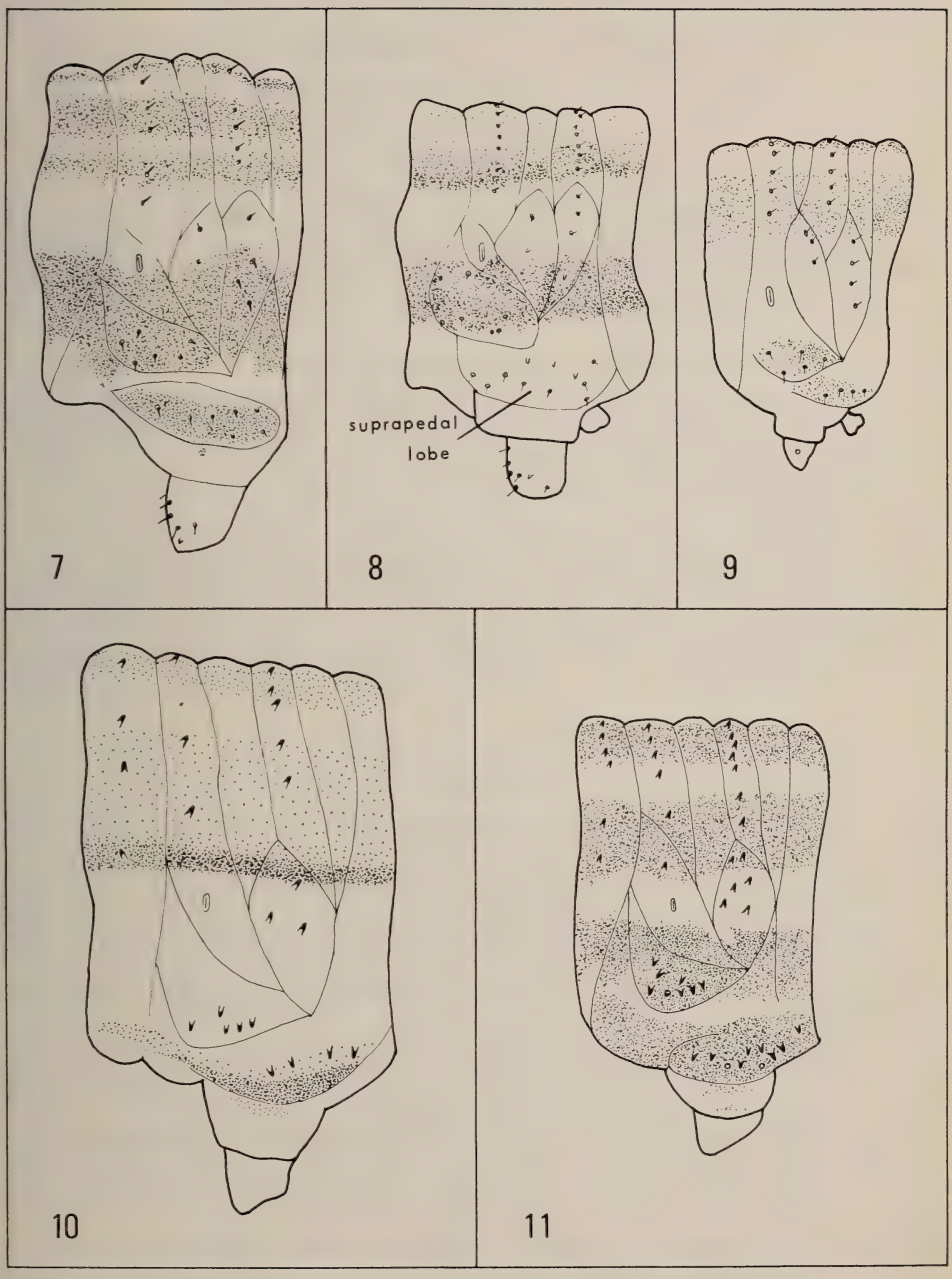
Head black or very dark red, without conspicuous markings; body dull greenish grey; subdorsal, supraspiracular, and subspiracular lines wide and black (Fig. 11). On spruce and balsam fir in June and July. ..... *Neodiprion abietis* complex

6. Larva in a loose silk shelter or in a silk tube that is usually brown, parchment-like, and open at both ends. 7

Larva in a frass nest or frass tube on old foliage of spruce; body colour variable with instar, later larvae shades of dull brown or khaki, sometimes with overtones of dusty yellow; broad middorsal and midventral lines and broken spiracular lines of maroon or reddish brown in late instars only; head dark brown to black (Eidt 1965). June and July. .... *Cephalcia fascipennis* Cress.



FIGURES 1-4. Larval antennae. 1, *Pikonema alaskensis* (Roh.) (antenna variable); 2, *Diprion hercyniae* (Htg.); 3, *Neodiprion abietis* complex; 4, *Cephalcia* sp.
FIGURE 5. Head markings on larva of *Diprion hercyniae* (Htg.).
FIGURE 6. Dorsal aspect of last segment of Pamphiliidae larva.



FIGURES 7-11. Third abdominal segments of larvae. 7, *Pikonema alaskensis* (Roh.); 8, *Pikonema dimmockii* (Cress); 9, *Pristiphora lena* Kincaid; 10, *Diprion hercyniae* (Htg.); 11, *Neodiprion abietis* complex.

7. Larva in a silk tube. 8

Larva in a loose silk shelter (no larval descriptions available); on spruce and balsam fir from June to August (Middlekauff 1958). ....*Acantholyda maculiventris* (Nort.)
or *Acantholyda chicoutimiensis* (Huard)
or *Acantholyda* sp. A (Eidt)
or *Acantholyda* sp. B (Eidt)

8. Larva brown or orange, on spruce. 9

Larva bright green often with yellow overcast, on balsam fir or hemlock; dorsal line narrow, dark green; head about body colour, antennae brown, darker apically (Eidt 1969). June and July. ....*Cephalcia distincta* (MacG.)

9. Dorsal line brown or reddish; no black pigment laterally on abdomen.....10

Dorsal line black; lateral areas of abdomen with considerable black pigment; body dull greenish with pink tint; basal segments of subanal appendages and sclerotized posterior edge of segment 10 yellow (Eidt 1969). On white spruce from mid-July to early September. .....*Cephalcia nigra* Middlekauff

10. Body yellowish tan with broad distinct dorsal, spiracular, and ventral lines of brown, or maroon, also a narrow brown subpleural line;; sclerites and appendages black except in last instar when some, in whole or part, are yellow or brown; the mature nonfeeding larva is orange (Eidt 1969).

June to September. .....*Cephalcia provancheri* (Huard)
or *Cephalcia semidea* (Cress.)

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AN ADDITIONAL RECORD OF DISTRIBUTION FOR *TRECHUS CRASSISCAPUS* LINDROTH (COLEOPTERA:CARABIDAE)

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Abstract

The species *Trechus crassiscapus* Lindroth (Coleoptera: Carabidae) previously known from a small area in the northern Appalachians is recorded from Thunder Bay, Ontario; a western range extension of approximately nine hundred miles.

* * * * * *

While making a general ecological study of leaf litter invertebrates near the city of Thunder Bay, Ontario, several specimens of *Trechus crassiscapus* Lindroth were collected in pitfall traps. The specimens were all collected on October 19, 1970 even though twenty pitfall traps operated continuously from September 15 to October 31. Both a key to the Canadian species of *Trechus* and a description of *T.crassiscapus* by Lindroth (1961) were used for the identification of the specimens. The distribution according to Lindroth (1961) is as follows: "Strictly eastern and confined to a rather small area in and around the northern Appalachians". Records from Canada are Nfld: Many localities mainly in the west. E. Labr: North to Hopedale and Quebec: La Ferme. It also occurs in the mountains of Maine, New Hampshire, Vermont and northern New York. This northwestern Ontario record, therefore, represents a western range extension of some nine hundred miles.

The habitat in which the species was collected is situated beside the Trans-Canada Highway within the western limits of the city of Thunder Bay, known locally as the Airport By-pass. The area can be described as a black spruce bog. The dominant species are black spruce *(Picea mariana)* and tamarack *(Larix laricina),* the former being more plentiful. The shrub layer is comprised of speckled alder *(Alnus rugosa)* and swamp birch *(Betula pumila),* the latter occurring less plentifully. Heath shrubs such as Labrador tea *(Ledum groenlandicum)* and leather-leaf *(Chamaedaphne calyculata) also* occur. Leather-leaf is the more prominent. Bog Laurel *(Kalmia polifolia),* small cranberry *(Vaccinium oxycoccus)* and Creeping snowberry *(Gaultheria hispidula)* are also present in small numbers. The ground vegetation is made up mostly of sphagnum moss, the most prominent being *Sphagnum capillaceum* with smaller amounts of *Sphagnum palustre* and *Sphagnum magellanicum.* Various grass and hedge species are scattered in small quantities throughout the bog.

Examination of the peaty soil showed it to have an average pH of 4.1 in 25 samples; and an average organic content of 84% in 36 samples. Organic content was determined by loss on ignition method. This habitat is very similar to that in which *T. crassiscapus* is found in Newfoundland (see Lindroth 1961).

The specimens have been sent to Dr. G. E. Ball to be placed in the Strickland Museum, Department of Entomology, University of Alberta, Edmonton.

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THE LANDING OF BLOOD-SEEKING FEMALE BLACK-FLIES (SIMULIIDAE: DIPTERA) ON COLOURED MATERIALS

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Abstract

When six-inch squares of coloured material were placed on the human host in pairs, blood-seeking females of the black-fly, *Simulium venustum* Say, selected certain colours more often than others. Landing frequency varied inversely with the intensity of reflected light whether with neutral (white, greys and black) or with colours. Even when considering ultraviolet, the white paper with the higher ultraviolet reflectance was less frequented than the one with the lower ultraviolet reflectance. If intensity was constant, green, yellow and orange were less "attractive" than white and much less than maroon, purple or grey of the same intensity. The purer the colour the fewer flies landed on it. The "attraction" of the coloured materials varied directly with the ratio of the reflectance from 450-500 mμ over that from 500-550 mμ.

* * * * * *

Introduction

An understanding of factors affecting the attack of simuliids and other blood-sucking Diptera on their hosts may aid in controlling these insects; in protecting humans, mammals and birds from them; and in reducing disease. One basic influence on the number of simuliids attacking is the seasonal change in the abundance of different species emerging from nearby streams, although some may disperse for considerable distances, e.g., several miles even in forested temperate region (Davies, 1950; Peterson and Wolfe, 1956; Ussova, 1961; Bennett, 1963). However, the number of emerging flies living long enough to reach their hosts may be profoundly influenced by terrestrial environmental factors, such as, rainfall, moisture of the ground, and the evaporating power of the atmosphere (Davies, 1952). A theoretical hierarchy of host-seeking behaviour in simuliids and tabanids has been proposed by Smith (1966) as follows: 1) appetitive behaviour, 2) upwind orientation, 3) near orientation and 4) landing behaviour. Previously, Davies (1952) considered that black-flies near the host exhibited three stages of activity, namely, flying, landing on the host, and biting (blood-sucking). Each of these three is influenced by various meteorological factors; in general the influence on landing is the inverse of the influence on flying (Davies, 1952). The landed flies that bite, are affected only by the rate of change of atmospheric pressure, if the test area of skin is in the shade. However if this test area is exposed to the full sunlight, the number landing is reduced to ½ and the number biting of those landed also to ½. This was considered to be the effect of solar radiation increasing the rate of evaporation of water from the insect (Davies, 1952).

This preference of blood-seeking simuliids for shaded, darker regions of the host has been reported by several authors (Monchadskii and Radzivilovskaya, 1939; Breev, 1950; Zahar, 1951; Berzina, 1953). Having, in addition, observed black flies more frequently landing on certain coloured clothing both on the wearer and recently discarded nearby, the author conducted experiments in order to investigate in more detail the reaction of black-flies to different reflected

colours. However, attempts to attract them to squares of Airforce blue serge away from the host were unsuccessful, even when these materials were soaked in human, under-arm or general body perspiration or in artificial acidic and basic* perspiration (Davies D. M. unpubl. notes), although mosquitoes are attracted to cloth impregnated with human perspiration (Haddow 1942, Parker 1948, Brown 1951). Therefore, preliminary experiments were made with squares of coloured cloth placed on the human host, each colour being tested against black. Landing was greater on darker cloths, but was also influenced by hue, dark blue and brown being more frequented than black (Davies, 1951).

These preliminary results stimulated a more extensive research on the effect of reflected light on the frequency of landing of simuliids on the human host. The colours of the test materials were chosen according to the Munsell Color System, so that a wide range of intensities, hues and purities were used. A brief account of some of the results has already been published (Davies, 1961). By obtaining the reflectances of each test material at wavelengths from 300-700 mμ with a spectrophotometer, a more detailed study of the relation between attraction, and relative and total reflectance was made.

Materials and Methods

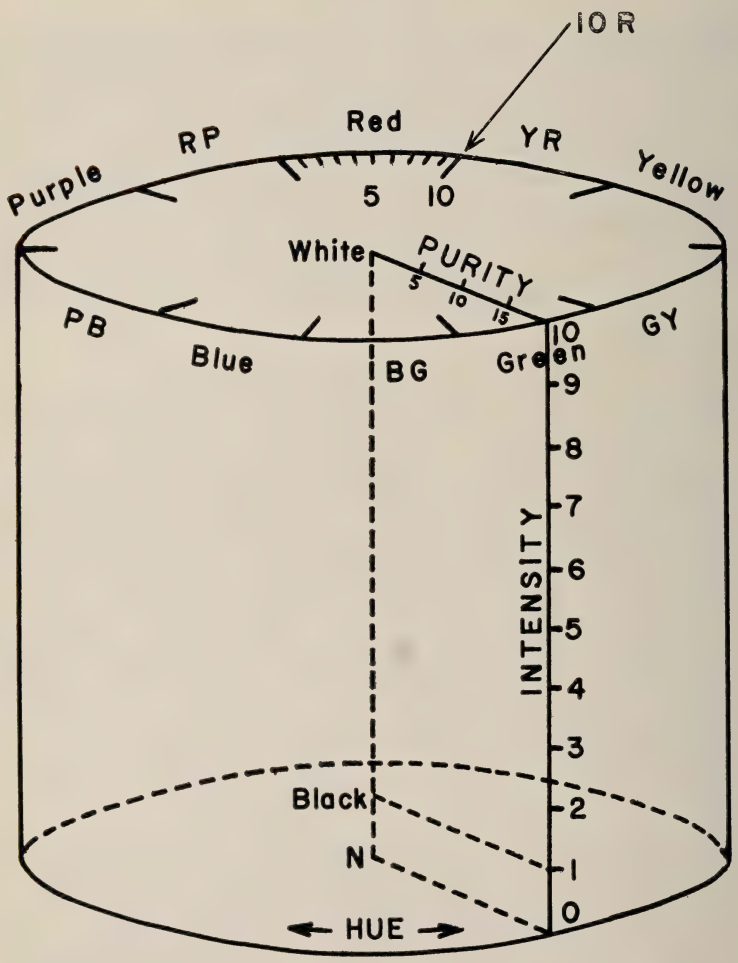
The Coloured Materials

The coloured cloths and papers used in this study of the visual responses of simuliids were classified according to the Munsell Color System (Nickerson, 1948), based on three components of colour, namely, intensity (lightness), hue ("wavelength pattern") and purity (chroma), each having many intergrades. The relation between these components is best shown by a cylinder (Figure 1). The hues are arranged as if the ends of the visible spectrum were joined to form a circle. These circles could be piled one on top of the other with the darkest at the bottom. Thus in the cylinder, hue is around the circumference (where P = purple, B = blue, G = green, Y = yellow, R = red and intermediate hues are represented by combinations of adjacent letters, such as, RP = red-purple). Intensity grades along the length of the cylinder, the central axis running from white at the top to black at the bottom. The third component, purity increases away from the central axis along any radius, thus neutral (N) is at the centre and greatest purity at the periphery. The Munsell notation for any colour is of this form 'hue x intensity/purity', e.g., 10R5/10. Using this system, tests could be conducted varying one of these components while the other two were kept relatively constant.

Certain coloured squares of papers (6 in. x 6 in.), most in a mat finish, were ordered from the Munsell Color Company Inc., Baltimore, Md., U.S.A. as follows: N 9.6/ ('Green Seal' zinc oxide white), N 7/ (light grey), N 4/ (dark grey), N 1/ (bone black no. 1), 2.5R4/8, 2.5YR4/8, 2.5B4/8, 2.5P4/8, 5.0R5/12, 5.0GY5/12 (glossy), 7.5PB5/12 and 7.5PB3/12. In addition six-inch squares of woollen flannel were dyed through the courtesy of Mr. M. L. Staples, Assistant Director, Textile Department, Ontario Research Foundation, Toronto to match Munsell colours according to the dye formulae of Mr. H. R. Davidson, General Aniline and Film Corporation, Easton, Pa., U.S.A. These coloured flannels were dyed to the following Munsell notations: 2.5R3/8, 5.0YR3/8, 10.0GY3/8, 2.5BG3/8, 2.5B3/8, 2.5PB3/8, 2.5P3/8, 2.5RP3/8, 2.5R7/8, 2.5Y7/8, 10.0

*10 g sodium chloride, 2.52 g sodium orthophosphate dibasic, and 1 g lactic acid 85% *or* 4 g ammonium carbonate per litre of water.

GY7/8, 10.0R5/16, 2.5Y7/14, 5.0GY7/12, 2.5B4/8, 2.5B5/8 and 2.5B6/8. Seven other cloths were used as well, i.e. two of cotton (N1.2/yellowish and N9+/), two of finely woven worsted wool (close to 5R3/12, and N5.1/), one Airforce blue worsted serge, and two Army khaki worsted serges. In order to compare differences in ultraviolet (UV) reflectances, two paper squares (6 in. by 6 in.) were prepared with Zinc Oxide (low UV) spread on one and Magnesium Carbonate (high UV) on the other. Each of these powders was mixed thoroughly with a solvent and



$$\text{MUNSELL NOTATION} = \text{hue}\ \frac{\text{intensity}}{\text{purity}} \qquad \text{e.g. } 10\,R\,\frac{5}{10}$$

FIGURE 1. Schematic relationship between the three parameters of the Munsell Color System: intensity (lightness), hue ("wave-length pattern") and purity (chroma). (After Nickerson 1948).

binder. the formula of which had little effect on light passage, namely, Gelva 7 (vinyl acetate) 20 g, dibutyl phthalate 5 g, toluol 5 g and acetone 25 g (W. N. B. Armstrong, pers. comm.). The resulting paste, in each case, was spread evenly over the paper with a special steel blade in an adjustable mount.

Method of Testing

The observer sat in the open but shaded from direct sunlight, and as much as possible out of the wind. In most tests a large black "sateen" cloth (doubled with dull side exposed) was spread across his outstretched legs. On this black flat surface, less than 1 ft above the ground, two squares (6 in. by 6 in.) of coloured paper or cloth were placed side by side, about one inch apart. The number of black-flies landing on each was counted simultaneously during a two-minute interval. In each experiment three squares of different colours were used so that each pair was tested three times and each square was on the left side (or right side) three times, i.e., AB, AC, BC, CA, CB, BA, BC, AB, CA. In this way bias due to changing environmental conditions, especially those changing regularly in one direction, could be minimized.

Determining the Species of Black Flies

Usually before or after each experiment, a collection of flies was made by sweeping a net (mouth = 1 ft in diam.) forty times in a figure 8 at arm's length (Davies, 1951). Occasionally in July 1951, flies that had landed were collected as well. All these flies were preserved in 70% ethanol and later identified to species.

Measuring Environmental Factors

Three light measurements were made in the shade at each experiment with a Weston 'Master' Illuminator (Model 715), two with it held two inches above a white (mat) painted board (6 in. by 6 in.). The first measured the reflected light from the board when it was horizontal and the second the maximum reflected light obtained by tilting the board from the horizontal. The third measurement was of the incident light skylight when the meter was pointed to the zenith. The first and third measurements were also made with an ultraviolet filter (No. 5840, Corning Glass Co.) over the opening of the meter, which allowed the passages of wavelengths from 295 mμ to 405 mμ. The temperature, relative humidity and atmospheric pressure were being recorded nearby, and observations on cloud cover, wind, and precipitation were also noted.

Determination of Attractancy of the Coloured Materials

Many coloured squares were compared directly as to their attractancy, that is, to the frequency of flies landing on them (see Appendix, Tables IV and V). From the figures obtained, the percentage of flies landing on each member of a pair could be calculated, and in addition an approximate attractancy value for each of the coloured materials from each set of experiments could be determined by totalling the percentages in each column and then dividing each total by that of the least attractive colour which became 1.0 (Appendix, Table VII). However, time permitted only a few, or no, direct comparisons of some coloured materials. Therefore, some comparisons could only be calculated indirectly. In this way a weighted attractancy value for each coloured material, relative to the group of materials being tested, was also determined (see Appendix), and this was the value used in discussion.

Measurement of Spectral Reflectances from Each Material

For most materials, reflectances in the visible range of the spectrum were measured by the Section of Photometry and Colorimetry, Division of Physics, National Research Council of Canada on a General Electric Recording Spectrophotometer with a 10 mμ slit, the surface of the reference material being magnesium oxide deposited from burning magnesium. A working standard of V3-G7 Vitrolite glass was used to correct for specularly reflected light. For the following papers the reflectances in the visible range of the spectrum were supplied by the Munsell Color Company, Incorporated, who had three laboratories make the measurements for them, namely, N1/, N4/, N7/, N9.6/, 2.5B4/8*, 7.5PB3/12 and 5.0R5/12 at the Philadelphia Naval Yard (using a General Electric Recording Photometer); 2.5P4/8, 2.5R4/8* and 7.5PB5/12 at the Interchemical Corporation; and 5.0YR4/8* at the National Bureau of Standards, Washington, D.C. (*also measured by Defence Research Board of Canada, using a magnesium carbonate standard with a Beckman D. U. instrument). The reflectances in the ultraviolet range were made by the National Research Council of Canada, according to the absolute method of Taylor (1920) with more recent refinements using a magnesium oxide standard, except for the cloths used by Davies (1951) which were measured by the Defence Research Board of Canada. The reflectances obtained by this method overlapped the other reflectances in the 400-420 mμ range, and the slight discrepancies in the figures were smoothed arbitrarily.

The black cloth used as a surround during most experiments had a low reflectance, almost similar at all wavelengths (Table VIII). The average reflectance from 300-700 mμ was 2.5 and from 400-700 mμ was 2.7. Unfortunately no reflectances of the light khaki surround were obtained but the average reflectance was probably between 25 and 35.

Results

Species Composition of Black-flies During Experiments

Simulium venustum Say was the commonest species, comprising 94% of the female simuliids flying around the observer throughout the period of experimentation from late May to late July in 1951 and in June 1961 (Table I). In May, *Prosimulium fuscum* Syme and Davies twice formed a third of the flying population, and in late July, *Simulium parnassum* Malloch increased to 50-60% during the last three experiments of 1951. The only other species worth noting were *Cnephia mutata* (Malloch) in May and *Simulium decorum* Walker, and these, although flying about the observer, showed a lesser tendency to land than the three other species. Seldom did a male fly land. Therefore, the visual responses herein discussed relate largely to females of *S. venustum*.

Influence of Relative Intensity of Reflected Light on the Frequency of Landing

The coloured materials used in these experiments were chosen so that, according to the Munsell Notations, their hue ('wavelength pattern') and purity (chroma) remained constant but their intensity (lightness) varied. In the first set of 32 experiments the neutral Munsell papers from black to white (N1/, N4/, N7/ and N9.6/) were used. The relative percentages of the flies landing on each pair of papers using a black background is shown in Table VII of the Appendix. By summing the percentages for each paper and then giving the value of 1.0 to

TABLE I. The Relative Abundance of Different Simuliid Species in Netting Collections during the 1951 Season and in June 1961.

Simuliid species	Female abundance in percent					
	1951					1961
	May 24-31	June 1-14	June 15-28	June 29-July 11	July 12-22	June 6-8
Prosimulium fuscum S. & D.	4.0	0.5	0	0	0	0.7
Cnephia mutata (Mall.)	2.9	0.6	0	0	0	0.2
Simulium decorum Wlk.	3.2	0.3	0.9	6.8	16.8[3]	0.6
Simulium parnassum Mall.	0	0	0.3	5.0	24.1[4]	0
Simulium venustum Say[1]	89.4	98.0	98.8	86.5	58.6	98.3
Other species[2]	0.5	0.7	0	1.7	0.5	0.2
Total number of flies	1209	2086	699	659	191	873
Number of experiments	29	50	50	27	14	23

[1] May include a few females of *Simulium verecundum* Stone and Jamnback.

[2] *Simulium aureum* Fries complex, *S. latipes* (Mg.) complex, *S. tuberosum* (Lund.) complex and *S. vittatum* Zett.

[3] Only one quarter of those flying landed.

[4] On July 22 at 7:30 p.m. mostly *S. parnassum* landed; the few *S. venustum* were weak.

white, the least attractive paper, relative attractancy figures (direct values) for each paper were calculated (Table VII). By considering indirect as well as direct comparisons, properly weighted attractancy figures were determined (see Appendix and Table VI and VII). Although the two greys and white showed an inverse attractancy with intensity, black was less attractive even than light grey (Figure 2a lowest curves). This was more marked with lower incident light. The relation of attractancy with the average reflectance, either from 300-700 mμ or from 400-700 mμ (Table VIII) or with the reflectance curve (Figure 2b), was similar to that with the Munsell Notations. This result with black could have been because the black surround (background) used gave no contrast with the black test paper. Therefore, similar tests were made with a light khaki, rather than a black, surround. The attractancy value of black was now higher than that of light grey, but it was still less than that of dark grey (Table VI and Figure 2a top solid line). The influence of surround was shown also when comparing dark grey with light grey or with white, but the effect was less than with black.

The next set of six experiments compared three other neutral colours (N1.2/ yellowish, N5.1/ and N9/), the cloths used by Davies (1951). The results were similar to those of Davies (1951), the so-called black being the most attractive and the white the least (Figure 2a top broken line). When the average reflectances (Table VIII) and the reflectance curve (Figure 2b) were compared with those of the neutral Munsell papers, the black cloth appeared to be really a very dark grey, the grey cloth a little lighter than the N4/ paper, and the white cloth less intense than the 9.6/ paper, i.e., really a very light grey.

The effect of the relative intensity of reflected light on attractancy was also observed with woollen flannel dyed different lightnesses of blue (2.5B 3/8, 2.5B 4/8, 2.5B 5/8, 2.5B 6/8). Again the frequency of landing varied inversely with the intensity (Figures 3a and b). The greater attractancy of a darker colour of the same hue and purity was shown by two red squares (5.0R 3/12 cloth and 5.0R 5/12 paper), by two purple-blue papers (7.5PB 3/12 and 7.5PB 5/12) and by two green-yellow squares of woollen flannel (10.0GY 3/8 and 10.0GY 7/8) (Figures 4, 5 and 6 respectively). Although two other green-yellow squares (5.0GY 5/12 glossy paper and 5.0GY 7/12 woollen flannel) were used in experiments, the comparison of their attractancy was obtained only indirectly by calculation, but again the colour of lower intensity was more attractive (i.e., attractancy values of 2.65 to 1.00 respectively).

The Munsell intensities from material to material followed the same trend as the average reflectance from 300-700 mμ (or from 400-700 mμ) for each material as measured by the spectrophotometer (Tables VIII and IX). Therefore, as expected when the attractancies of the coloured materials were compared with their average reflectances, the same inverse relationship was shown as with the Munsell intensity notations, except for the black paper (Figure 2a and b). The reflectances from 300-700mμ for the neutral and coloured materials indicated that, when the total intensity was greater, the intensity at all wavelengths was greater but this was less marked in the ultraviolet for the neutral materials (Tables VIII and IX).

Influence of Ultraviolet Reflectance on the Frequency of Landing

Two white paper squares were specially prepared, one with a low reflectance in the ultraviolet (ZnO) and the other with a high ultraviolet reflectance ($MgCO_3$). These were compared with the white (N9.6/) Munsell paper, also a ZnO preparation, and with the black (N1/) Munsell paper. The spectrophotometric readings in the ultraviolet confirmed the difference in the ultraviolet reflectances of the

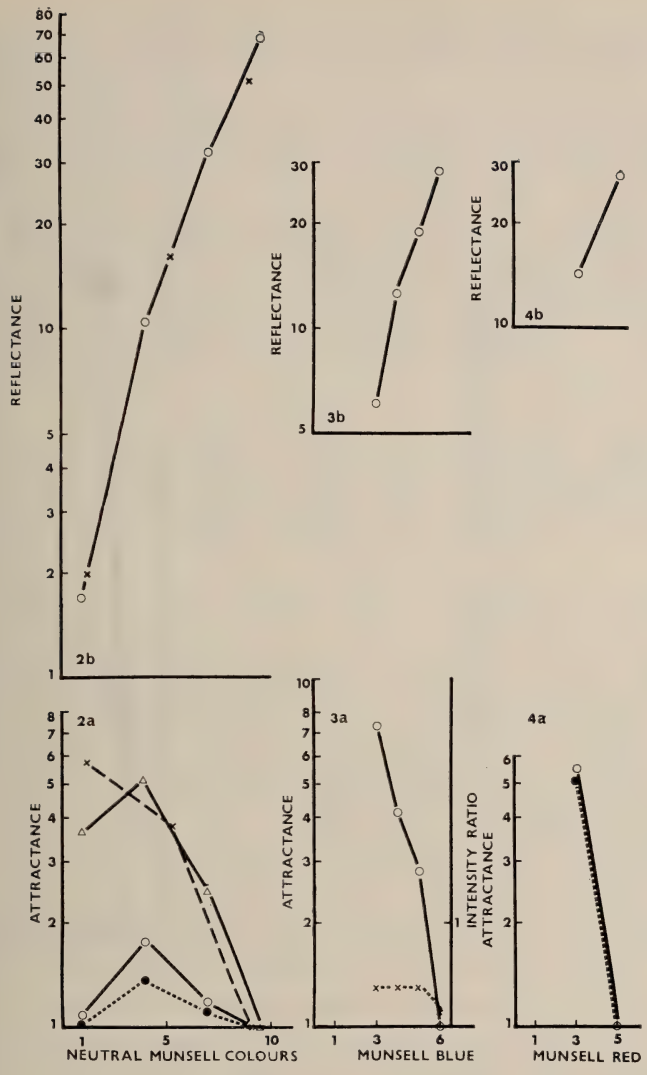
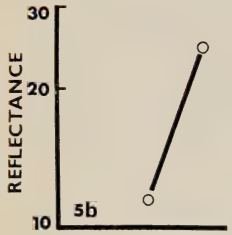
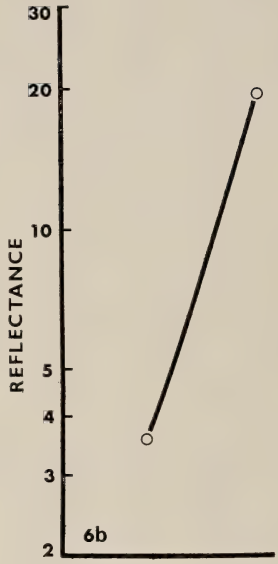


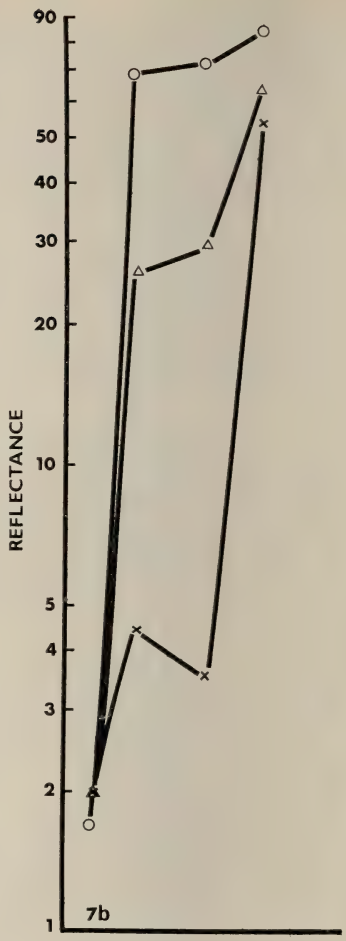
FIGURE 2a. The relative attractance of various neutral colours (from black = N1/ to white = N9.6/) to female black-flies when test squares on a black background (o---o) direct values and o——o weighted values; 27 tests and 2134 flies) or when on a khaki background (△ —— △ weighted values; 5 tests and 1993 flies). Neutral colours used by Davies (1951) were retested (x---x weighted values; 6 tests and 1988 flies). b. The average reflectance of each colour from 300 to 700 mμ.

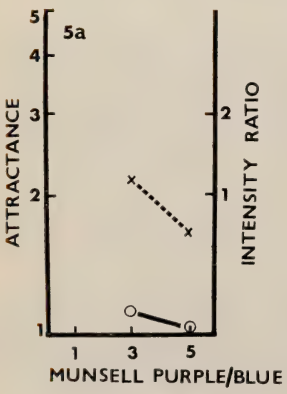
FIGURE 3a. The relative attractance of blue woollen flannels of different intensities (2.5B 3/8, 2.5B 4/8, 2.5B 5/8, 2.5B 6/8) to female black-flies (o——o weighted values; 10 tests and 1600 flies). The reflectance ratio (450-500 mμ/500-550 mμ) is also shown (x---x). b. The average reflectance of each colour from 300-700 mμ.

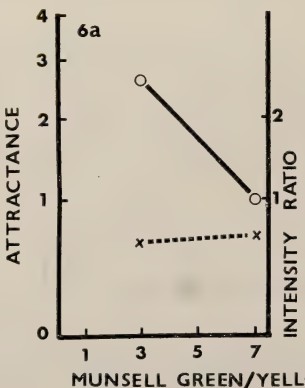
FIGURE 4a. The relative attractance of a red finely woven worsted wool (5.0R 3/12) and a Munsell paper with mat finish (5.0R 5/12) to female black flies (o---o) direct values and o——o weighted values; 2 tests and 1085 flies). The reflectance ratios (450-500 mμ/500-550 mμ) both equal to 1.0. b. The average reflectance of each colour from 300-700 mμ.


REFLECTANCE
30
20
10
5b


REFLECTANCE
30
20
10
5
4
3
2
6b


REFLECTANCE
90
50
40
30
20
10
5
4
3
2
1
7b


5a
ATTRACTANCE
INTENSITY RATIO
5
4
3
2
1
2
1
1 3 5
MUNSELL PURPLE/BLUE


6a
ATTRACTANCE
INTENSITY RATIO
4
3
2
1
0
2
1
1 3 5 7
MUNSELL GREEN/YELLOW

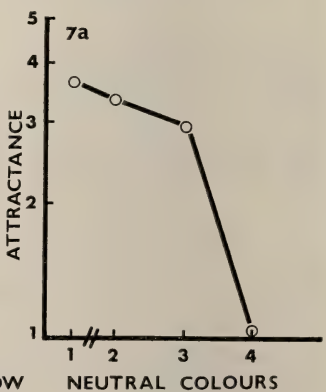

7a
ATTRACTANCE
5
4
3
2
1
1 2 3 4
NEUTRAL COLOURS

FIGURE 5a. The relative attractance of two purple-blue papers with mat finish (7.5PB 3/12 and 7.5PB 5/12) to female black-flies (o——o weighted values; 9 tests and 443 flies). The reflectance ratios 450-500 mμ/500-550 mμ are also shown (x---x). b. The average reflectance of each colour from 300-700 mμ.

FIGURE 6a. The relative attractance of two green-yellow woollen flannels (10.0GY 3/8 and 10.0GY 7/8) to female black flies (o——o weighted values; 7 tests and 202 flies). The reflectance ratios are also shown (x---x). b. The average reflectance of each colour from 300-700 mμ.

FIGURE 7a. The relative attractance of white papers (N9.6/) of different ultraviolet reflectances and of a black paper (N1/) to female black-flies (o---o) direct values, o——o weighted values; 21 tests and 988 flies). 1 = Munsell black, 2 = Munsell white, 3 = specially prepared zinc oxide layer on paper, 4 = specially prepared magnesium carbonate layer on paper. b. The average reflectance of each colour (x---x 300-350 mμ, △ --- △ 300-400 mμ and o——o 400-700 mμ). $MgCO^3$ has a low ultraviolet reflectance).

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white papers (Table VIII and Figure 7b). The black paper was the most attractive, and the two white squares with low ultraviolet reflectances, each had 2/3 as many flies land on them as did the black. The paper with the higher reflectance in the ultraviolet (though a lower reflectance in the visible range) had less than 1/3 the number land on it compared to the black (Figure 7a).

Influence of the Hue of Reflected Light on the Frequency of Landing

In the next series of experiments, the hue was varied while the Munsell notations for intensity and purity remained constant. In the first set of experiments the intensity was 3 and the purity 8, and eight different hues in dyed woollen flannels were compared (2.5P, 2.5PB, 2.5B, 2.5BG, 10.0GY, 5.0YR, 2.5R, 2.5RP). As can be seen in Table 2 and Figure 8, the flies frequented some hues more than others. When the least attractive colour, orange (YR), was compared with the most attractive, maroon (RP), 94% of the flies landed on the latter. Nearly as unattractive as YR were blue-green (BG) and yellow-green (GY), and almost as attractive as RP were purple (P) and purple-blue (PB). If the average reflectance from cloth to cloth (Figure 8b) had been more uniform, the difference in attractancy would have been more marked. This was true of the other three sets of experiments studying variation of the hue (see below).

In the second set of experiments the purity was still 8 but the intensity was higher at 4. Munsell papers of four different hues (2.5P, 2.5B, 5.0YR, 2.5R) were compared among themselves and with dark grey (N4/). As with the darker hues, purple (P) was the most attractive and orange (YR) was the least, being, in fact, less attractive than the grey of the same intensity (Table II and Figure 9).

A third set of experiments was done with the same purity (8) but the intensity was now 7. Two coloured papers (2.5Y, 2.5R) and one woollen flannel (10.0GY) were used in company with the light grey (N7/). In this case the red (R) was slightly less attractive than light grey, but yellow (Y) and yellow-green (GY) were much less attractive (Table II and Figure 10).

With purity increased to 12 and the intensity at 5, experiments were conducted on three Munsell papers (7.5PB, 5.0GY and 5.0R). Purple-blue was again the most attractive with green-yellow the least and red intermediate (Table II and Figure 11).

In the final experiments comparing hues, the Airforce blue, worsted serge was compared with two dark khaki, Army worsted serges, and these were also

TABLE II. The relative attractancy of all the coloured materials tested in relation to their reflectance ratio around 500 mμ. (p = paper, c = cloth, A = army, AF = airforce).

Colours of different intensities (Munsell colour notations)					Relative Attractancy	Ratio (mμ) 450-500 / 500-550
3	4	5	6	7		
2.5RP3/8					1000	2.2
2.5P3/8					668	1.9
2.5PB3/8					469	1.7
	2.5P4/8				445	1.8
7.5PB3/12					437	2.2
2.5R3/8					418	1.6
		7.5PB5/12			389	1.7
2.5B3/8					361	1.3
AF-blue					312	1.2
	2.5B4/8p				232	1.2
5.0R3/12					216	1.0
	2.5B4/8c				203	1.3
	2.5R4/8				191	1.2
		2.5B5/8			135	1.3
(10.0GY3/8					(113)	(0.60)
	5.0YR4/8				72.2	0.60
				2.5R7/8	64.9	1.1
			2.5B6/8		49.1	1.1
10.0GY3/8*					44.7	0.60
2.5BG3/8					44.6*	0.89
		5.0R5/12			43.8	1.0
5.0YR3/8					42.4	0.63
		5.0GY5/12			24.6	0.28
		10.0R5/16			20.2	0.99
A-khaki 1					17.1	0.78
				2.5Y7/14	16.3	0.10
				2.5Y7/8	15.9	0.36
				10.0GY7/8	13.1	0.64
				5.0GY7/12	9.27	0.34
A-khaki 2					6.82	0.74

*selected value (see Appendix text)

tested with two dyed flannels (2.5PB3/8 and 2.5R3/8). Few flies landed on the two khaki cloths and about 2/3 as many landed on the Airforce blue serge as on the purple-blue (PB) flannel (Table II and Figure 12).

When the Munsell intensities of the materials with varying hue were compared with the average reflectances from 300-700 mμ or from 400-700 mμ inclusive,

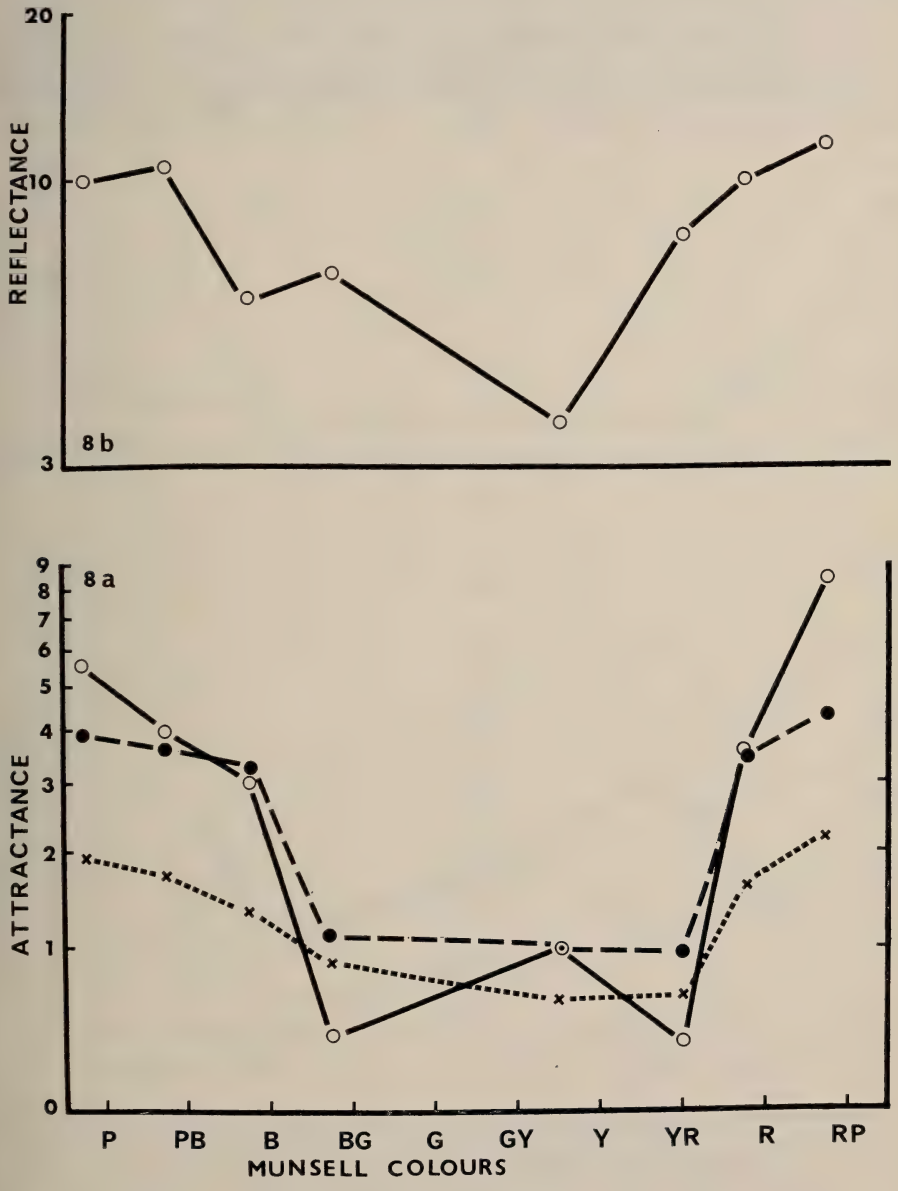


FIGURE 8a. The relative attractance of coloured woollen flannels (2.5P 3/8, 2.5PB 3/8, 2.5B 3/8, 2.5BG 3/8, 10.0GY 3/8, 5.0YR 3/8, 2.5R 3/8, 2.5RP 3/8) to female black-flies (o---o) direct values, o——o weighted values; 73 tests and 10,645 flies). The reflectance ratio (450-500 mμ/ 500-550 mμ) is also shown (x---x). b. The average reflectance of each colour from 300-700 mμ.

the results were less consistent than with the materials chosen for their Munsell intensity differences (Table IX). The only feature of the reflectance of the material to which attractancy was consistently related was the ratio of the reflectances from 450-500 mμ over those from 500-550 mμ (Table II).

Influence of the Purity of Reflected Light on the Frequency of Landing

Fewer tests were made in which purity varied while intensity and hue remained relatively constant. In one set of experiments, two red woollen cloths (2.5R 3/8 and 5.0R 3/12) were compared, and the one with purity 12 was half as attractive as the one with purity 8 (Figure 13), but it also had a higher average

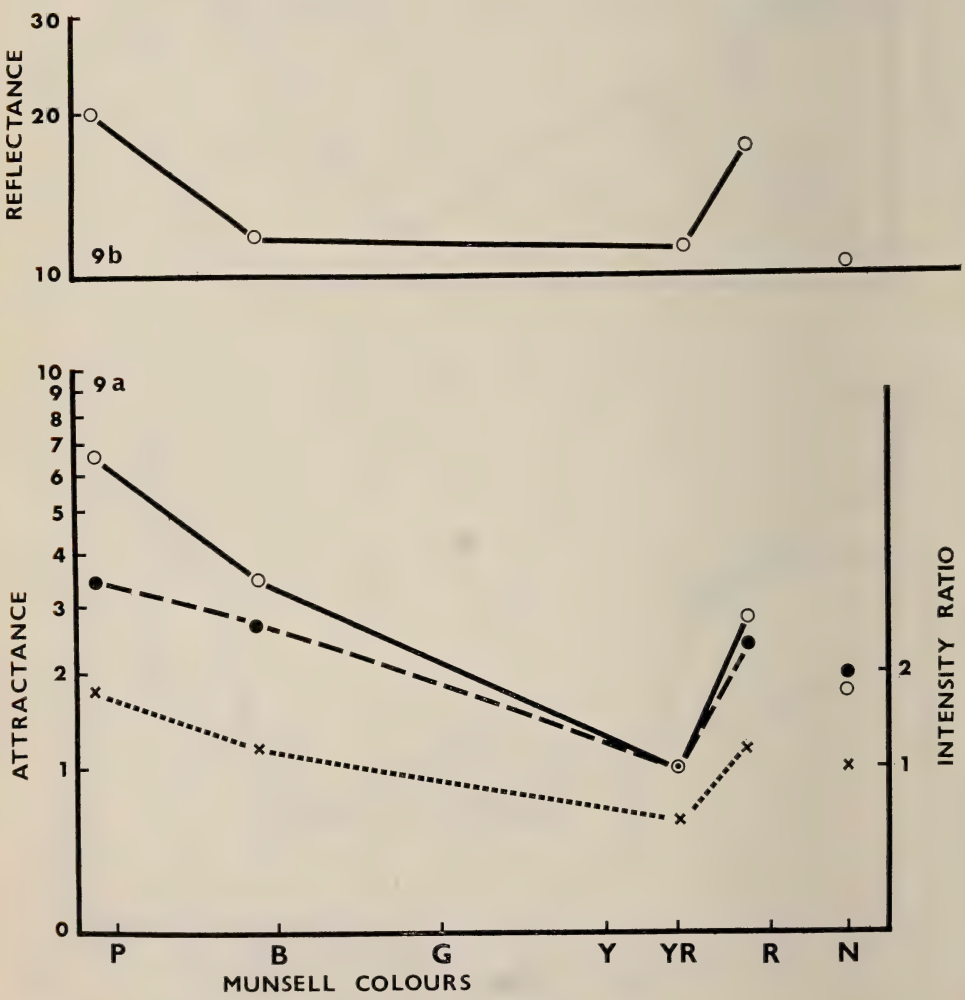


FIGURE 9a. The relative attractance of coloured Munsell papers (2.5P 4/8, 2.5B 4/8, 5.0YR 4/8, 2.5R 4/8) to female black-flies (o---o) direct values, o——o weighted values; 29 tests and 6435 flies). Grey (N4/) was also used in these tests. The reflectance ratios (450-500 mμ/ 500-550 mμ) are also shown (x---x). b. The average reflectance of each colour from 300-700 mμ.

reflectance. Two red squares of higher purity (5.0R 5/12 paper and 10.0R 5/16 flannel) were compared in other tests. Again the cloth of higher purity was only half as attractive as the other (Figure 14) but in this case the cloth of higher purity had a lower average reflectance. When two purple-blue squares of different purities (2.5PB 3/8 flannel and 7.5PB 3/12 paper) were compared, the same trend was shown but was less marked than with the red materials (Figure 15) and may have resulted from intensity differences as well. Two green-yellow flannels of differing purities (10.0GY 7/8 and 5.0GY 7/12) exhibited again that attractancy was less at higher purities (Figure 16), although the latter had a lower average reflectance. Nevertheless the neutral grey of the same intensity was frequented by many more

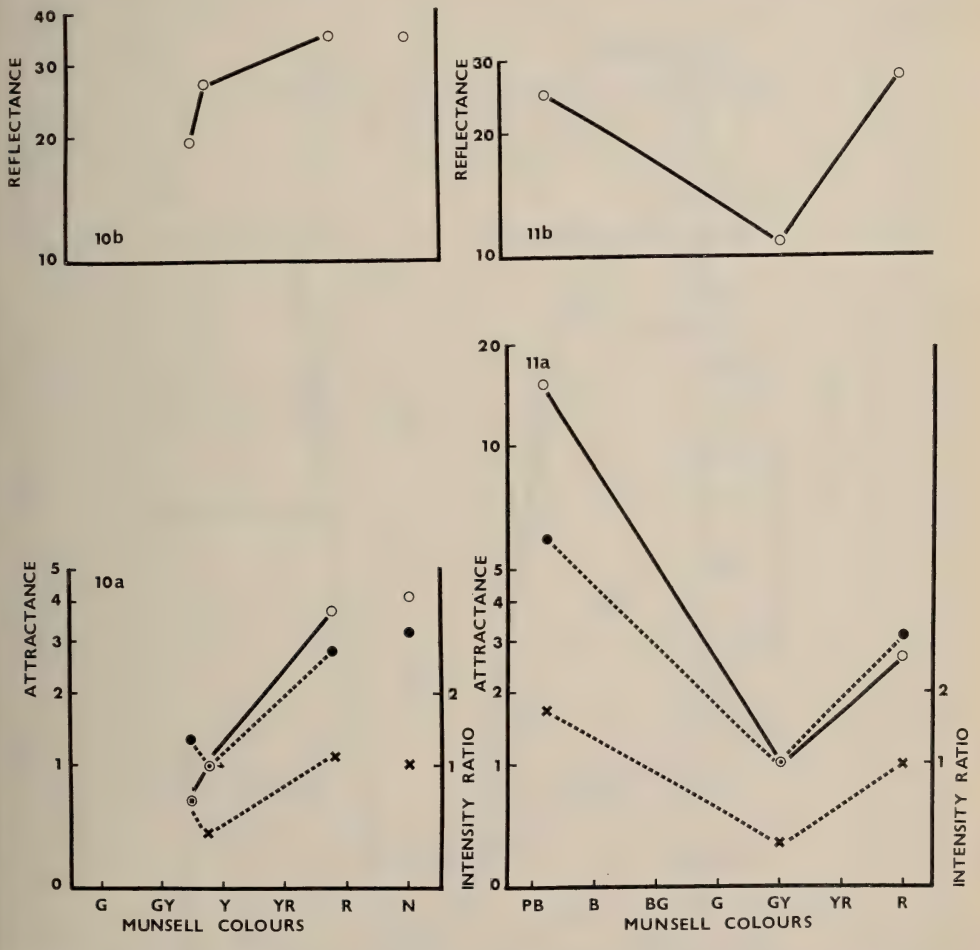


FIGURE 10a. The relative attractance of coloured woollen flannels (10.0GY 7/8, 2.5Y 7/8, 2.5R 7/8) and a Munsell grey paper (N7/) to female black-flies (o---o) direct values, o——o weighted values; 14 tests and 1082 flies). The reflectance ratios (450-500 mμ/500-550 mμ) are also shown (x---x). b. The average reflectance of each colour from 300-700 mμ.

FIGURE 11a. The relative attractance of coloured Munsell papers (7.5PB 5/12 mat finish. 5.0GY 5/12 glossy, 5.0R 5/12 glossy) to female black-flies (o---o) direct values, o——o weighted values; 8 tests and 302 flies). The reflectance ratios (450-500 mμ/500-550 mμ) are also shown x---x). b. The average reflectance of each colour from 300-700 mμ.

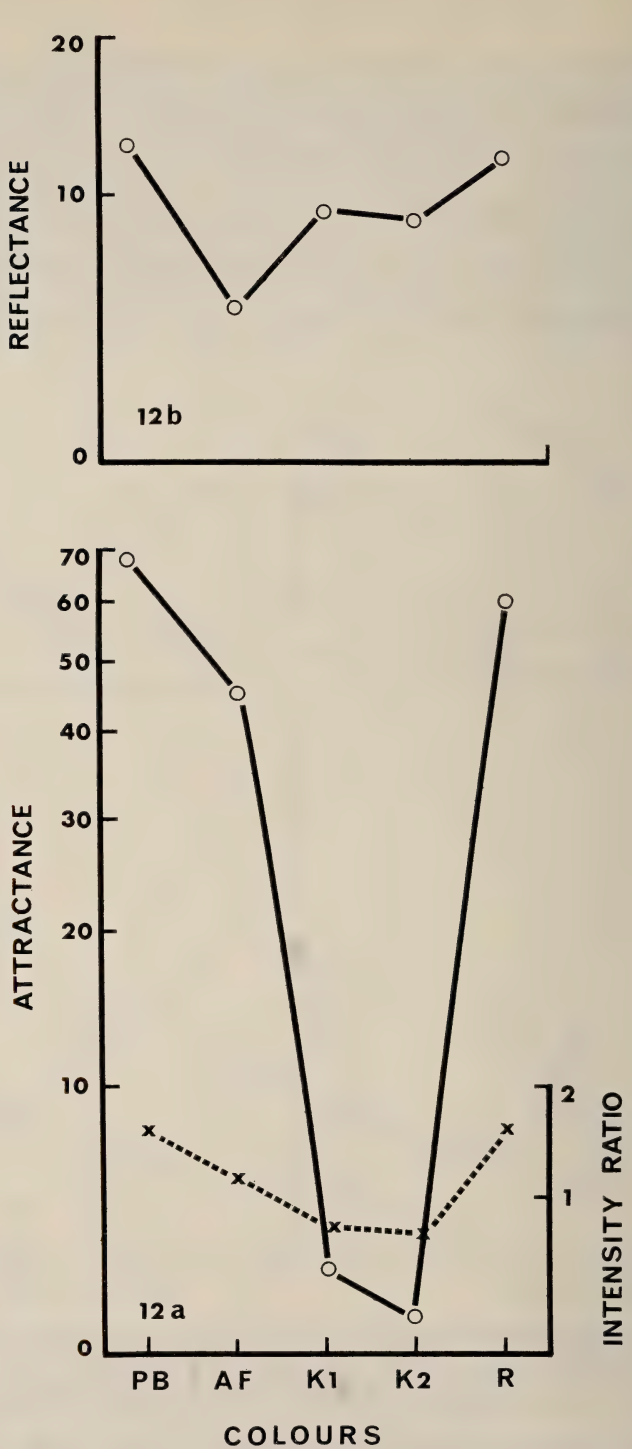
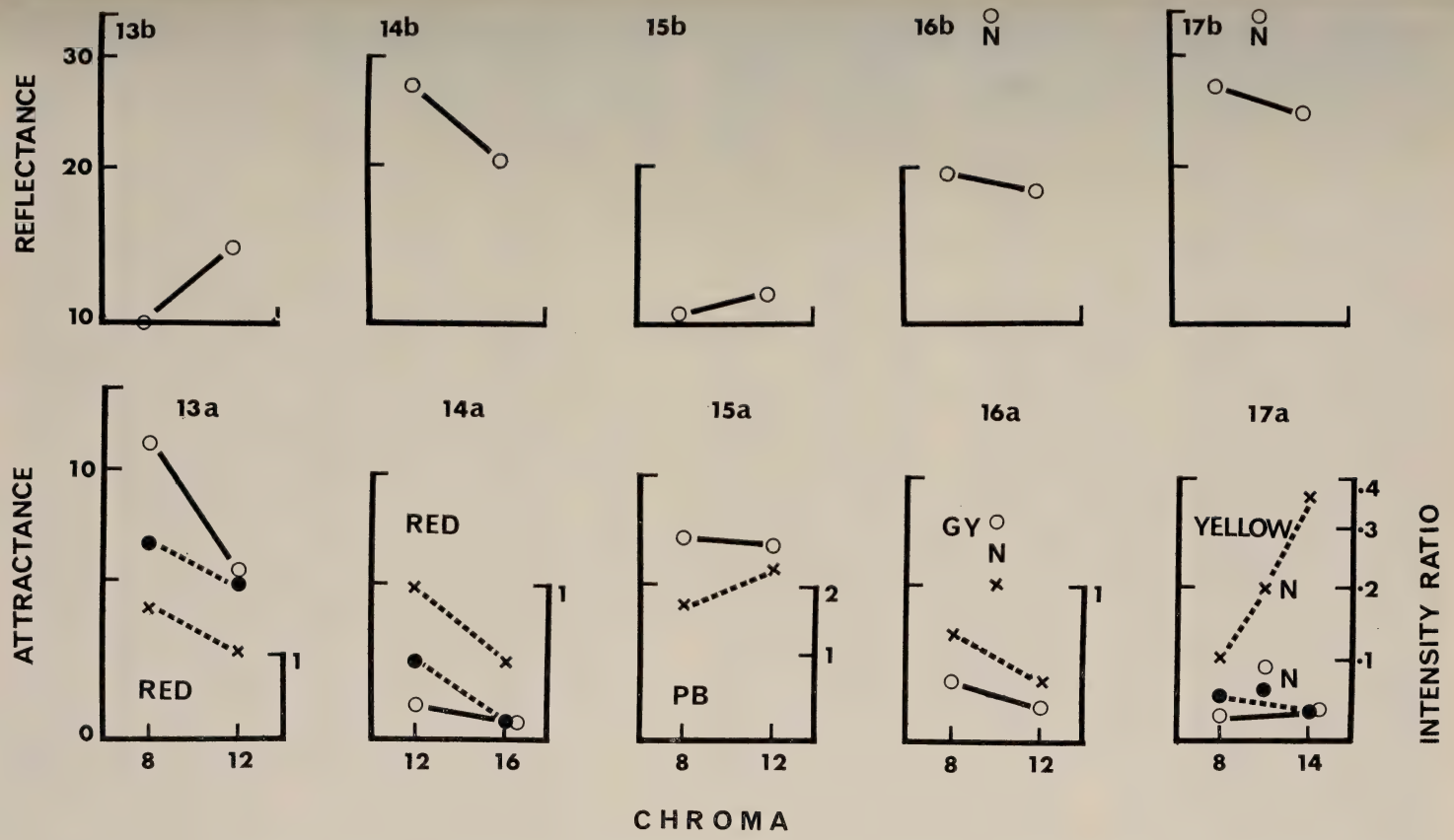


FIGURE 12a. The relative attractance of various coloured materials to female black-flies; 3 tests and 1965 flies (o——o) weighted values; reflectance ratios (x---x). AF = airforce blue worsted serge, K1 and K2 = army khaki worsted serges, PB = 2.5PB 3/8 and R = 2.5R 3/8, the last two being woollen flannels. b. The average reflectance of each colour from 300-700 mμ.



FIGURES 13a-17a. The relative attractance of various coloured materials to female black-flies (o---o) direct values o——o weighted values, reflectance ratios x---x). 13a. Reds (2.5R 3/8 woollen flannel, 5.0R 3/12 finely woven worsted wool); 2 tests and 2120 flies. 14a. Reds (5.0R 5/12 Munsell paper with mat finish, 10.0R 5/16 woollen flannel); 3 tests and 950 flies. 15a. Purple-blues (2.5PB 3/8 woollen flannel, 7.5PB 3/12 Munsell paper with mat finish); 9 tests and 460 flies. 16a. Green-yellows (10.0GY 7/8 and 5.0GY 7/12 woollen flannels) and grey (N7/); 7 tests and 109 flies. 17a. Yellows 2.5Y 7/8 and 2.5Y 7/14 woollen flannels) and grey (N7/); 2 tests and 422 flies.

FIGURES 13b-17b. The average reflectance of each colour from 300-700 mμ.

flies than either of the green-yellow cloths. In tests with two yellow flannels of different purities (2.5Y 7/8 and 2.5Y 7/14) the trend was broken using weighted values (but not using direct values), the one with the higher purity being slightly more attractive (Figure 17); however, the average reflectance of the latter was slightly less and its reflectance ratio higher, possibly overriding the effect of its higher purity.

The reflectance ratio (450-500 mμ/500-550 mμ) also seemed to be a feature to which attractancy of the cloths varying in purity could be related with the exception of the purple-blue (PB) where intensity differences may have predominated.

Influence of Incident Skylight on the Frequency of Landing

Tests were conducted at all times of the day, but more in the late afternoon and evening because more black-flies were attacking at these times. Also tests were made under all types of sky condition from clear to heavy overcast. This means that the relative intensity at each wavelength and the total intensity of the incident skylight varied during the tests.

The intensity of the light reflected from a horizontal white board varied from 0.2-2000 f.c. (80% of the readings between 100-1500 f.c.) and incident skylight from the zenith varied from 0.8-7000 f.c. (80% of the readings between 250-5000 f.c.).With an ultraviolet filter the intensity of incident light (295-405 mμ) from the zenith varied from 6.5-200 f.c.

Over the range of conditions during the tests there was no clear effect of incident light intensity on the black-fly's discrimination of various coloured materials, except in the case of neutral colours as mentioned previously.

Discussion

Many features of the host influence the attack of blood-seeking Diptera. The habitat in which the host is, may determine which species and how many flies will attack. Some simuliid species restrict their blood-sucking to hosts on or near the water (Anderson, 1956; Davies and Peterson, 1956, 1957; Bennett, 1960), others attack more at ground level away from the water, and still others predominately well above the ground, even in the treetops (Bennett, 1960; Anderson and DeFoliart, 1961). The movement of the host, whether jostling the support of the fly, creating air currents, or just offering visual stimulation has been observed to be important in several groups of blood-seeking Diptera (Philip, 1931; Sippell and Brown, 1953; Monchadskii, 1956; Thorsteinson, 1958; Haufe and Burgess, 1960; Kalmus and Hocking, 1960 p. 17; Wenk and Schlörer, 1963). Also determining which species and how many flies will attack may be the size, area, and shape of the host (Hearle, 1932; Haddow, 1954, 1956; Davies and Peterson, 1956, p. 648; Dow, Reeves and Bellamy, 1957; Thorsteinson, 1958; Davies, 1959; Downe, 1960; Anderson and DeFoliart, 1961 p. 722; Wright and Kellogg, 1964), and its contrast with the surrounding environment (Bracken, Hanec and Thorsteinson, 1962). Odours and moisture are also important in the orientation of blood-seeking flies to the host, involving water vapour, carbon dioxide, amino acids and other chemicals (see review on mosquitoes by Clements, 1963 and Roessler and Brown, 1964; Fallis and Smith, 1964b). Some odours have given unusual host specificity in simuliids (Lowther and Wood, 1964; Fallis and Smith, 1964a).

The influence of light on the attack of blood-seeking simuliids involves the general flying activity, a photokinesis (Davies, 1952 p. 309; Berzina, 1953; Wolfe and Peterson, 1959) and the directed movement towards the host, a phototaxis. The latter seems to involve two stages, the attraction of the fly to the host from a distance, and the near-orientation and landing on a part of the host. It was thought that reflected colours of high intensity, presumably contrasting sharply with the background, might aid in attracting blood-seeking black-flies from a distance (Davies, 1952), but that dark colours, particularly those of certain hues, favoured their landing on a particular part of the host (Davies, 1951, 1961). The effect of light on the attack of other blood-seeking insects has been reported by a number of workers (see below). In addition, observations have been made on the influence of reflected light on landing of flies in a behavioural phase other than blood-seeking, e.g., landing to rest or to oviposit, and the insect's response to colours at these times may be quite different than when landing to feed.

In this research observations were made on the frequency of landing by blood-seeking females of *Simulium venustum* on coloured materials placed between them and their host. In general, the lower the intensity of the reflected light, whether neutral (black, greys and white) or a specific hue, the more 'attractive' was the material. However, black (even on a light khaki surround) was less frequented than dark grey. This was shown also in *Haematopota* (a tabanid) by Barrass (1960b, Table II). Therefore there appears to be a peak of 'attractancy' at low intensities of reflected light, above and below which 'attractancy' decreases. This effect of the relatively lower 'attractancy' of black was more marked at lower intensities of incident light, similar to the findings of Dalmat (1955, p. 326) with Guatemalan simuliids landing on dark- and far-skinned humans and of Barrass (1960b, Tables I and II) wth *Haematopota,* but differing from the work of Brown (1951) with *Aedes* mosquitoes.

That blood-seeking Diptera land more frequently on surfaces (on the host) reflecting less light has been reported by a number of workers: for simuliids by Monchadskii and Radzivilovskaya (1948), Breev (1950), Dalmat (1955), Davies (1951, 1961), Crisp (1956) and Spalatin *et al.* (1961 - p. 32); for culicids by Brett (1938), Gjullin (1947), Brown (1951, 1954, 1955), and Smart and Brown (1956); for tabanids by Philip (1931), Bromley (1952), Tashiro and Schwardt (1953) and Barrass (1960b); for muscids *(Lyperosia* and *Haematobia)* by Beach and Clark (1904), Marlatt (1910), Thomsen (1938) and Hammer (1941); and for muscids *(Glossina)* by Barrass (1960a). Other authors have mentioned that Diptera land on darker materials away from the host, but these flies may have been seeking a resting place rather than food, e.g., ceratopogonids *(Culicoides)* by Hill (1947); culicids by Gilbert and Gouck (1957); tabanids by Hansens (1947, 1952) and Bracken *et al.* (1962); and *Musca domestica* L. by Freeborn and Berry (1935), Waterhouse (1948), Hecht (1963) and Arevad (1965).

It appears from the present study that black flies discriminate, in addition, between different hues, although it is difficult in this type of investigation to be conclusive. However, the differences in the 'attractancy' of different hues are unexplained by only a higher or lower average intensity of reflected light (from 300 or 400 mμ to 700 mμ) or by differences in reflectances in other wavelength ranges or in single wavelengths. The only feature of reflectance to which these 'attractancies' were related, was the ratio of the reflectance from 450-500 mμ over that from 500-550 mμ. Some colours, such as, blue-green, green-yellow, yellow and yellow-red, even with low intensity values, were less frequented than white or the greys of equivalent Munsell intensity (Figures 10, 16, 17). Other colours, e.g.,

dark purple, blue and red, were more 'attractive' than the dark grey of equivalent Munsell intensity, even though the total reflectance of the grey was half that of purple, much less than red and less than blue (Figure 9).

Diptera of a number of families, mostly blood-seeking females, have been observed landing more frequently on certain colours than on others: for simuliids by Monchadskii and Radzivilovskaya (1948), Davies (1951, 1961); for culicids by Nuttall (1901), Ko (1925), Brett (1938), Gjullin (1947), Brown (1951, 1954, 1955) and Gilbert and Gouck (1957); for tabanids by Hansens (1947); and for the house fly by Waterhouse (1948). There seems to be sometimes considerable differences between species even within one family. *Aedes* mosquitoes generally land more frequently on black, red and usually blue than on green, yellow or white (Ko, 1925; Brett, 1938; Gjullin, 1947; Brown, 1954), which is in general agreement with the present results with *Simulium venustum,* but in *Anopheles* the preference is reversed (Ko, 1925). The three authors, other than Ko, were certainly dealing with blood-seeking mosquitoes. The work of Gilbert and Gouck (1957) is somewhat at variance with other work with *Aedes,* but they used hanging coloured disks and their mosquitoes may have been landing to rest rather than to feed. Kalmus and Hocking (1960) found *Aedes* to be attracted more often by red than by black or white as was also *Anopheles earlei* Vargas, but Nuttall (1901) found *Anopheles maculipennis* Meigen landed more frequently on dark blue and much less on red. These authors were also testing landing frequencies on materials away from the host. Bracken *et al* (1962) found that tabanids landed much less frequently on green and yellow spheres than on those of other hues or various greys.

It is difficult to compare these results because in some cases no mention is made of whether the colour is dark or light. Sometimes the total intensity is measured, but often with a photometer more sensitive to certain wavelengths. A worthwhile comparison may be made between the present results with simuliids and those of Brown (1954) with *Aedes* mosquitoes because certain tests were made with the same materials, that is, with woollen flannels dyed to Munsell standard colours (Table III). Also the reflectances of these cloths was measured with the same spectrophotometer for wavelengths from 300-700 mμ. The order of attraction of the colours for female *Aedes* mosquitoes differed from that for female *Simulium venustum,* although, for both, the green-yellow and yellow were the least frequented, and dark purple and dark red the most. However red, at both intensities, was more attractive to *Aedes* than to *Simulium.* That *Aedes* were more attracted to red than expected was considered by Brown (1954) as an indication of their low sensitivity to longer wavelengths.

Both Brown (1954) with *Aedes* and Bracken *et al* (1962) with tabanids suggested that the infrequency of landing on green was because of its lack of contrast with the background of green vegetation. The reflectance curve for green leaves, as given by Popp and Brown (1936), is similar to 10GY x/8 (intensity "x" probably averaging about 5). However, in the present study the test squares were on a black surround, so that the above suggestion seems inappropriate to explain why few simuliids landed on the green materials. This behaviour may, on the other hand, indicate adaptation.

The effect of reflected light on females of *Simulium venustum* which are about to oviposit is in marked contrast to that on blood-seeking females of this species. Gravid females of *S. venustum* oviposit mainly on green, glaborous vegetation, standing or trailing in running water (Davies and Peterson, 1956). However, they have been noted a few times ovipositing on yellow leaves (Smith and Davies,

unpublished notes). These are the colours least frequented by the blood-seeking females. It might be also of interest to mention that oviposition occurs mostly in the shade and that if a ray of direct sunlight falls on the ovipositing simuliid, it usually flies away (Davies and Peterson, 1956 p. 643). A similar difference in colour preferences depending on behavioural phase, was shown by 'hungry' cabbage butterflies, *Pieris brassicae* (L.) and those exhibiting 'a preoviposition drumming behaviour' (Ilse, 1928, 1937). Green and greenish-blue materials, selected for preovipositional behaviour, were among the colours which produced no 'spontaneous feeding response', and the converse was true of other colours, such as, red, yellow, blue and violet.

In addition to studies on the response of insects to reflected light, much work has been done on their reaction to incident light sources. Weiss (1944, 1946) and others have shown that in many species attraction increases with incident light intensity up to certain maxima. In some insects, such as, most culicids, there is a negative phototaxis (Headlee, 1937 Christophers, 1960). In others, such as the simuliid *Cnephia dacotensis* Dyar and Shannon, there is little or no response to incident light (Twinn, 1936). The advantage of incident light is that for testing, it can more easily be made monochromatic or of a narrow band of wavelengths.

Goldsmith (1961), Dethier (1963) and Burkhardt (1964) have reviewed the work on colour vision in insects, based mainly on experiments with incident light. Dethier stated that "the relative efficiency of different wavelengths in eliciting phototactic responses has been measured for a number of species" of insects, and continued "Whether the curves describing the relative effectiveness of the different wavelengths in eliciting phototactic responses are true action spectra

TABLE III. Comparison of the attractancy of the same dyed woollen flannels to blood-seeking females of *Aedes*, mainly *punctor*, and of *Simulium venustum*, together with different aspects of the reflectances of the cloths in the ultraviolet and visible wavelength ranges.

NRC code	Munsell notation	Atractancy to *Aedes*		Atractancy to *Simulium*	Average reflectance in mμ			Reflectance ratio
		Rotation tests[1]	Paired tests[2,3]	Paired tests[3]	300-700	400-700	475-625	450-500 mμ / 500-500 mμ
E-4	2.5P3/8	60	53	139	10	12	11	1.9
E-1	2.5R3/8	87	87	87	10	12	9	1.5
E-3	2.5B3/8	43	59	75	6	7	13	1.3
E-8	2.5B4/8	42	49	41	12	14	24	1.3
E-5	2.5R7/8	54	57	12	35	42	57	1.1
E-2	10.0GY3/8	16	47	8	4	4	10	0.6
E-6	2.5Y7/8	22	34	4	26	31	55	0.4
E-7	10.0GY7/8	17	29	2	20	23	60	0.6

[1]from Brown (1954 - last column Table V); figures unchanged
[2]from Brown (1954 - third column Table VII)
[3]figures changed relative to the attractancy of dark red (2.5R3/8) being taken as 87.

(relative energy for constant effect) or not, all show that the most effective part of the spectrum for *Musca, Apis* and *Drosophila* is the near ultraviolet and ,to a lesser degree, the blue-green".

Although an insect may show differences in its response to colour depending on its behavioural phase, as discussed earlier, electrophysiological studies have confirmed the more general behavioural findings, especially those involving incident light (see reviews Dethier, 1963 and Mazokhin-Porshnyakov, 1969).

The responses to two black-fly species, *Simulium argyreatum* Meigen (as *decorum* Wlk.) and *S. ornatum* Mg., to incident light, presented to the flies (equal numbers of each sex) as a spectrum on a glass surface, were studied by Doby, Bernard and David (1956). The adults of *S. argyreatum* were used 1-5 days after emergence and those of *S. ornatum* 2-24 hours after emergence. Females of *S. ornatum* are presumably anautogenous (L. Davies 1957 a, b), but often in Diptera, blood-seeking occurs only 1-2 days after emergence (in simuliids Davies and Peterson, 1956 p. 627; L. Davies, 1957b, p. 541; McMahon 1968 and in culicids Burgess and Young, 1944; Laarman, 1955; and MacDonald, 1956). Therefore, the behaviour of *S. ornatum* females of this age may not have been showing a 'biting drive' during their experiments. Females of *S. argyreatum* are autogenous for the first ovarian cycle (Davies, D. M. and Györkös 1968 unpubl. notes) so that it is also uncertain whether the females of *S. argyreatum,* used in the experiments of Doby *et al.* (1956), were eliciting blood-seeking behaviour. The possible differences in the behavioural state of their flies and their use of incident rather than reflected light makes it difficult to relate their work to the present study.

The experiments of Doby *et al.* (1956) showed that *S. argyreatum* adults were most attracted by wavelengths from 520-540 mμ (green). These colours were among the ones least landed upon by blood-seeking black-flies in the present study. McMahon (1968) found that, when Cinemoid colour filters were placed in front of a 110-watt pearl lamp, a higher percentage of *S. ornatum* females fed on blood in the presence of orange or yellow incident light than with other colours; green and blue were intermediate and few flies fed under violet or red illumination. However these experiments appear to have involved the feeding behaviour of flies that had already landed. Possibly the results of Doby *et al.* (1956) and of McMahon (1968) can be resolved with those of the present study. Indeed, blue-green and green (and possibly yellow) may stimulate simuliids to fly and not to land, but once the females have landed orange and yellow, and to a lesser extent green, increase their biting activity.

Doby *et al.* (1956) were unable to prove differences in the response of black-flies to red, infra-red and total dark, and certain *Aedes* mosquitoes seem insensitive to incident or reflected infra-red (Peterson and Brown, 1951; Brown 1954). However, several Diptera can distinguish red (Bertholf 1932), especially with prior dark adaptation (Fingerman and Brown 1953, Mazokhin-Porshnyakov 1969).

Vargas (1945) found that, at night, traps with blue lights attracted more black-flies than those with yellow lights. Frost (1954) and Grebelsky, Kovrov and Byaenkova (1963) collected female simuliids at night with an ultraviolet light. Several other insects have been shown to be more attracted to the near ultraviolet and the blue-green regions of the spectrum of incident light (see above).

It may be that incident light because it is the brightest source stimulates flying and other locomotion in insects. Mazokhin-Porshnyakov (1969) suggests that light, especially ultraviolet, causes insects to fly to open spaces. The hues of inci-

dent light that concentrate insects, such as, green (Doby *et al.,* 1956) and ultraviolet (Frost, 1954; Grebelsky *et al.,* 1963) for simuliids, are not those that promote landing. On the other hand, purple, maroon, red and blue, especially dark shades, do evoke landing of blood-seeking simuliids. We have also attracted blackflies to incandescent lights at night; sometimes the flies collected outside the window of a lighted room, but if the window was opened they continued to fly to the light source. Dark grey and black materials were more frequently landed on by blood-thirsty simuliids. This same pattern may have been operating when a white material with a low ultraviolet reflectance was selected more often than whites with a higher reflectance below 400 mμ.

In the present experiments, the female blood-seeking simuliids may have been attracted to land on the host mainly, or at least in part, by non-visual factors emanating from the human, but the placing of coloured materials between the host's skin and the fly had an important influence on whether the fly would land. With coloured squares of the same hue and purity, i.e., roughly the same pattern of reflectance across the spectrum of wavelengths from 300-700 mμ, intensity was the factor to which attractance was inversely related. However, when hue or purity varied, intensity being more or less constant, the reflectance pattern had a marked influence on attractance. The attractance of the cloths of different hues and purities (chromas) was not related to the intensity of any particular wavelength or wavelength band, but only to the ratio of the reflectance from 450-500 mμ over that from 500-550 mμ. This may be related in some way to insects in general showing a greater sensitivity (attraction) to wavelengths near 500 mμ than to other visible wavelengths, and having some retinula cells sensitive to green and others, possibly only in the lower half of the eye, sensitive to yellow-green or blue (Mazohkin-Porshnyakov, 1969). Further study is needed to understand these findings more fully.

Summary

Light reflected from the host was shown to be important in the landing of blood-seeking females of *Simulium venustum* Say.

When six-inch squares of materials in pairs were interposed between the human host and the flies, some colours were more frequented than others.

Using neutrals (white, greys and black) against a black background, dark grey was more "attractive" than light grey and white, but black was less attractive than either grey. On a light khaki background, black became more attractive than light grey but white attracted relatively fewer flies than before. The inverse relation between attractance and the intensity of reflectance was shown as well by materials of different hues. Also a white material with a lower ultraviolet reflectance was more "attractive" than one with a higher ultraviolet reflectance.

When intensity remained more or less constant, certain hues were frequented less than were greys of the same intensity, whereas other hues were frequented much more than the corresponding greys. Thus, ultramarine-blue through chartreuse-green and yellow to orange were much less attractive than maroon, purple and blue-purple of similar intensity, with red and blue somewhat intermediate.

"Attractance" was inversely related to the purity (chroma) of the colours.

Attractance of the flies to materials varying in hue and purity was related directly to the ratio of the reflectance from 450-500 mμ over that from 500-550 mμ.

The behavioural state and physiological age of the fly should be considered when judging response to stimuli, such as, light. Some colours (green and yellow), frequented least by blood-seeking females of *Simulium venustum*, were those most used for oviposition sites by gravid females of the same species.

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Appendix

Collection and Tabulation of Data

The squares of coloured material were tested in pairs and in each experiment, consisting of nine such tests, three different squares were used. Each square was to the right in an equal number of tests as to the left. The numbers of flies landing on each square of a pair were counted simultaneously for a 2-min. period and were recorded as in Table IV and the direct comparisons totalled. Other experiments using at least two of the same squares were combined and totalled so that figures of greater weight resulted (Table V). By using the percentage landing on each member of a pair, other tables were compiled (e.g., Tables VI and VII). These percentages were totalled and the coloured square with lowest figure was given the value 1 and the others related to it (e.g., Table VII).

TABLE IV. The raw data from test #9 on May 25, 1951 at 19:30 - 20:00 hrs (EDT) showing the number of female black flies landing on three different neutral Munsell papers when tested in pairs. A = N9.6/, B = N4/ and C = N1/.

A:B	19:69	C:A	84:11	B:C	116:168
A:C	13:90	C:B	87:104	A:B	36:152
B:C	55:100	B:A	93:34	C:A	169:35
Total A:B	= 59:343	A:C	= 89:314	B:C	= 355:275

TABLE V. Compilation of all the tests comparing the frequency of landing on the four neutral Munsell papers (N9.6/, N7/, N4/, N1/) when a light khaki background was used. Test numbers in parenthesis.

Munsell Code	N1/ (C)[a]	N4/ (B)	N7/ (D)	N9.6/ (A)
N1/ (C)[1]	——	275:355(9) 39: 58(12) 13: 48(14) 17: 30(21) 13: 18(102) 357:509 41.2: 58.8%	11: 18(14) 34: 8(21) 15: 7(102) 60: 33 64.5: 35.5%	314: 89(9) 39: 11(12) 353:100 77.9: 22.1%
N4/ (B)		——	48: 23(14) 34: 9(21) 12: 15(102) 94: 47 66.7: 33.3%	343: 59(9) 30: 8(12) 373: 67 84.8: 15.2%
N7/ (D)			——	••[b]
N9.6/ (A)			••[b]	——

[a] symbols as in Table 4 in brackets; N7/ (D) did not appear in test #9 (Table 4) but did in three subsequent tests.

[b] comparison not tested directly.

TABLE VI. Landing frequency of female black flies on neutral papers against a light khaki background, expressed as percentages of the total landing on the pair tested. In this set, only intensity is involved. In parenthesis are the number of tests followed by the number of flies. The relative attractancy value (weighted value) for each 'colour' is given at the bottom in parentheses based on 5 tests and 1993 flies. No direct values could be calculated because not all pairs were compared directly.

Munsell code	N1/	N4/	N7/	N.96/
N1/	—	58.8 (5-866)	35.5 (3-93)	22.1 (2-453)
N4/	41.2	—	33.3 (3-141)	15.2 (2-440)
N7/	64.5	66.7	—	••[1]
N9.6/	77.9	84.8	••[1]	—
Total	183.6	210.3	••	••
W. values	(3.7)	(5.3)	(2.5)	(1.0)

[1] not compared directly

TABLE VII. Landing frequency of female black flies on neutral papers against a black background, expressed as percentages of the total landing on the pair tested. In this set, only intensity is involved. In parenthesis are the number of tests followed by the number of flies. The relative attractancy value (direct value) for each 'colour' is given at the bottom, based on 27 tests and 2134 flies, and also the weighted value in parentheses.

Munsel Code	N1/	N4/	N7/	N9.6/
N1	—	61.3 (11-421)	53.1 (16-384)	48.4 (13-368)
N4/	38.7	—	46.0 (19-176)	33.3 (11-427)
N7/	46.9	54.0	—	49.2 (16-358)
N9.6/	51.6	66.7	50.8	—
Total	137.2	182.0	149.9	130.9
D. values	1.0(5)	1.4	1.1(5)	1.0
W. values	(1.1)	(1.8)	(1.2)	(1.0)

However all paired combinations could not be tested directly in the field (Table VI) and other tests had few data. Therefore to gain a better picture of the relative "attractance" of the different coloured squares, weighted attractance values were calculated (see method below).

Calculation of Weighted Attractance Values

Comparisons using the following neutral papers (see Table V), N1/, N4/, N7/ and N9.6/

	N1/	N4/	N7/	N9.6/	Total
1	357	509	—	—	886
2	60	—	33	—	93
3	353	—	—	100	453
4	—	94	47	—	141
5	—	373	—	67	440
6	—	—	—	—	—

Equations:

$$509N1/ - 357N4/ = 0$$
$$33N1/ - 60N7/ = 0$$
$$100N1/ - 353N9.6/ = 0$$
$$47N4/ - 94N7/ = 0$$
$$67N4/ - 373N9.6/ = 0$$

The purpose is to obtain the best fit for values of N1/, N4/, and N7/ when N9.6/ = 1, for all five equations. (If direct comparisons had been made between N7/ and N9.6/, there would be six equations).

If a_i, b_i, c_i and d_i are components of N1/, N4 , N7 and N9.6 respectively, then we form the following table:

a_i	b_i	c_i	d_i	W_i
509	−357	0	0	866
33	0	−60	0	93
100	0	0	−353	453
0	47	−94	0	141
0	67	0	−373	440

$$a_i N1 + b_i N4 + c_i N7 + d_i = 0$$

$$\sum_{i=1}^{6} W_i (a_i N1 + b_i N4 + c_i N7 + d_i)^2 = \text{min.}$$

$$\sum W_i (a_i N1 + b_i N4 + c_i N7 + d_i) a_i = 0$$

1) $$\left(\sum w_i a_i^2\right) N1 + \left(\sum w_i a_i b_i\right) N4 + \left(\sum w_i a_i c_i\right) N7 + \sum w_i a_i d_i = 0$$

2) $$\left(\sum w_i a_i b_i\right) N1 + \left(\sum w_i b_i^2\right) N4 + \left(\sum w_i b_i c_i\right) N7 + \sum w_i b_i d_i = 0$$

3) $$\left(\sum w_i a_i c_i\right) N1 + \left(\sum w_i b_i c_i\right) N4 + \left(\sum w_i c_i^2\right) N7 + \sum w_i c_i d_i = 0$$

1) $[866\ (509)^2 + 93\ (33)^2 + 453\ (100)^2]\ N1 + 866\ (509)\ (-357)\ N4 + 93\ (33)\ (-60)\ N7 + 453\ (100)\ (-353) = 0$

2) $866\ (509)\ (-357)\ N1 + [866\ (-357)^2 + 141\ (47)^2 + 440\ (67)^2\ N4 + 141\ (47)\ (-94)\ N7 + 440\ (67)\ (-373) = 0$

3) $93\ (33)\ (-60)\ N1 + 141\ (47)\ (-94)\ N4 + [93\ (-60)^2 + 141\ (-94)^2]\ N7 = 0$

One continues to combine these equations to solve for N1/, N4/ and N7/ with the result being as follows: when N9.6/ = 1, then N7/ = 2.5, N4/ = 5.3 and N1/ = 3.7 (bottom Table VI). This was also done even when all pairs were compared directly (bottom Table VII)*.

Arranging All Coloured Materials in Order of Attractancy Values

In order to compare all the coloured squares used in the experiments, the relative attractancy of the most frequented colour, red-purple (2.5RP 3/8), was given the value 1000 and the attractancy values (relative to RP) for the other colours were calculated by comparing stepwise the value of each pair of materials. In this way the second column on the right in Table II as derived. In one case, one test involving 10.0GY 3/8 appeared to indicate an unreal attractancy for this colour (see value in parenthesis) so that another value was obtained by deleting this test (see other value of 10.0GY 3/8 also in Table II).

Summary of Reflectance Values

For certain coloured materials, the results of the spectrophotometric analysis were sent to the author as graphs and for others as tables. The average reflectance values for each material are summarized showing values at 50 mμ intervals (average of values ± 25 mμ on either side of each wavelength designation) from 300 to 700 or 750 mμ (Table VIII and IX). Average reflectances in the ultraviolet (300 to 400 mμ), "visible" (400 to 700 mμ) and total (300 to 700 mμ) wavelength ranges are also indicated for each material as well as the ratio 450-500 mμ/ 500-550 mμ (Tables VIII and IX).

*Tables detailing results of tests with other coloured materials are available from the author.

TABLE VIII. The reflectances at different wavelengths for the various neutral materials as measured spectrophotometrically, and the average reflectances over different wavelength ranges for each colour. The approximate Munsell Colour designation of each is also listed. P = paper, C = cloth, N = neutral, ZnO = zinc oxide spread on paper, and $MgCO_3$ = magnesium carbonate spread on paper.

Colour	Munsell Code	Wavelengths in mμ										Ranges in mμ			450-500 mμ
		300	350	400	450	500	550	600	650	700	750	300-400	400-700	300-700	500-550 mμ
Black C Surround	N	1.7	1.7	2.9	2.8	2.6	2.5	2.6	2.8	3.0	3.4	2.1	2.7	2.5	1.1 (1.06)
Black P	N1/	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.6	—	2.0	1.6	1.7	1.0
Black C	N1.2/	2.2	2.0	2.0	2.0	1.9	1.9	1.9	2.0	2.0	2.5	2.1	2.0	2.0	1.0
Dk grey P	N4/	3.1	3.5	13.8	12.2	12.3	12.5	12.5	12.4	12.5	—	6.8	12.6	10.5	1.0
Md. grey C	N5.1/	4.0	11.5	15.9	17.9	17.6	16.1	15.9	17.8	27.9	37.2	10.5	18.4	16.1	1.1 (1.05+)
Lt. grey P	N7/	3.2	4.0	41.0	43.0	43.5	44.1	44.0	44.2	45.4	—	16.1	43.6	34.7	0.99
White C	N9/	32.7	44.2	51.3	55.0	55.6	55.6	55.0	53.1	54.3	54.3	42.7	54.3	50.8	0.99
White P	N9.6/	3.7	4.5	71.0	86.5	89.8	90.3	90.2	90.2	90.9	—	26.4	87.0	88.1	0.98
White P	ZnO	3.0	4.0	80.5	91.4	92.1	92.2	92.3	92.5	92.8	93.2	29.2	90.5	71.2	1.0
UV White	$MgCO_3$	40.8	70.5	84.9	85.7	87.1	87.9	88.4	88.9	89.2	89.7	65.4	87.4	80.4	0.99

TABLE IX. The reflectances at different wavelengths for the various coloured materials (cloth unless indicated p = paper) as measured spectrophotometrically, and the average reflectance over different wavelength ranges for each colour. The approximate Munsell Colour designation of each is also listed. (P = purple, B = blue, G = green, Y = yellow, R = red).

Munsell Code	Wavelengths in mμ										Average (mμ)			Ratio
	300	350	400	450	500	550	600	650	700	750	300-400	400-700	300-700	450-550 / 500-550
2.5P3/8	2.5	5.8	21.0	15.0	5.8	4.9	6.3	6.5	21.3	50.7	9.8	11.5	9.9	1.94
2.5P4/8p	3.5	3.8	38.3	32.0	14.7	10.7	12.8	24.7	40.9	—	15.2	24.9	20.2	1.84
2.5PB3/8	2.2	7.6	12.4	19.3	14.8	5.0	2.5	2.6	29.9	62.9	7.4	12.3	10.7	1.72
7.5PB3/12	3.5	4.2	24.7	30.4	14.6	5.5	4.3	5.2	12.0	—	10.8	13.8	11.6	2.24
7.5PB5/12	3.5	4.0	47.7	51.1	32.4	17.3	14.3	16.4	32.8	—	18.4	30.3	24.4	1.68
AF-blue	1.0	3.0	4.0	4.6	4.0	3.2	3.0	3.7	9.8	20.7	2.7	4.9	4.0	1.19
2.5B3/8	2.5	6.0	3.8	12.4	18.7	4.8	1.3	1.2	4.0	27.0	4.1	6.6	6.1	1.32
2.5B4/8	3.5	12.6	8.1	21.9	26.6	11.2	3.7	5.0	19.5	58.9	8.1	13.7	12.5	1.28
2.5B4/8p	5.9	6.9	13.2	20.9	30.9	11.5	5.6	4.7	6.6	—	8.7	13.3	11.8	1.22
2.5B5/8	2.3	14.7	14.7	36.2	40.5	20.3	6.9	4.4	30.0	64.2	10.6	21.9	18.9	1.26
2.5B6/8	4.5	19.5	25.1	41.7	48.2	35.5	18.6	18.2	42.7	61.7	16.4	32.9	28.2	1.07
2.5BG3/8	2.0	8.0	6.6	6.9	20.9	10.3	2.4	1.5	2.3	15.6	5.5	7.3	6.8	0.892
10GY3/8	4.0	2.3	1.6	1.5	9.2	8.6	2.7	1.3	1.3	7.8	2.6	3.7	3.6	0.601
5.0GY5/12	4.4	3.5	3.3	2.5	6.5	25.6	15.2	10.5	23.7	67.1	3.7	12.5	10.6	0.280
10GY7/8	2.0	10.0	10.5	13.3	42.3	44.9	26.8	13.7	11.7	42.9	7.5	21.9	19.5	0.639
5.0GY7/12	2.4	2.4	2.0	2.0	23.5	50.6	34.1	19.8	22.5	52.5	2.3	22.1	17.7	0.344
2.5Y7/8	2.0	8.5	7.9	9.1	11.1	44.8	48.0	47.9	61.2	64.7	6.1	32.9	26.7	0.362
2.5Y7/14	1.5	2.1	1.6	1.4	3.7	47.7	50.0	50.4	62.0	64.9	1.7	31.0	24.5	0.099
Khaki 1	1.0	3.0	3.9	4.1	5.7	6.8	7.1	9.7	20.3	34.6	2.6	8.2	6.8	0.784
Khaki 2	1.0	3.0	3.0	3.4	5.2	6.4	7.0	9.0	18.3	32.4	2.3	7.5	6.3	0.741
5.0YR3/8	1.2	1.0	1.4	1.3	1.2	2.8	12.8	14.1	35.0	60.6	1.2	9.8	7.9	0.625
5.0YR4/8p	3.8	3.5	4.3	4.6	5.9	11.5	22.9	24.0	24.0	23.5	3.9	13.9	11.6	0.604
2.5R3/8	3.5	3.5	4.9	4.4	2.2	1.9	12.5	17.2	39.7	57.0	4.0	11.8	10.0	1.61
5.0R3/12	1.0	1.5	2.3	2.2	2.1	2.2	9.0	46.0	62.8	68.7	1.6	18.1	14.3	1.00
2.5R4/8p	4.3	4.0	14.1	10.5	7.9	7.1	16.6	41.8	50.4	—	7.5	21.2	17.4	1.23
5.0R5/12	4.5	5.0	10.0	8.5	7.6	8.2	46.7	75.8	79.1	—	6.5	33.7	27.3	1.02
10R5/16	1.4	2.1	2.1	1.2	1.2	4.0	47.0	62.2	65.2	66.6	1.9	26.1	20.7	0.462
2.5R7/8	2.5	17.0	27.8	33.3	24.3	26.1	58.7	61.9	63.8	64.4	15.8	42.3	35.0	1.14
2.5RP3/8	1.5	3.8	14.6	10.8	3.9	2.9	10.5	18.7	39.4	61.8	6.6	14.4	11.8	2.16

INSECTICIDES AND THE SOIL ENVIRONMENT[1, 2]

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Abstract

Recently, because of adverse ecological side-effects, there has been much criticism of the use of chemicals, particularly the organochlorine insecticides for insect control. Use of these compounds is now being restricted and new, "less persistent" compounds are being substituted at a rapid rate. These are assumed to be less ecologically hazardous, but factual information is lacking. In the soil ecosystem, most organochlorine insecticides did not seriously affect beneficial non-target soil animals, other than the arthropods, or soil microorganisms. Some, especially the cyclodiene insecticides, did drastically influence populations of beneficial soil arthropods both in terms of biomass and numbers. Results of a study on the behaviour of one of the newer insecticides. Dasanit® (0,0-diethyl 0-[p-(methylsulfinyl) phenyl] phosphorothioate) in soil are summarized. Laboratory studies indicated that persistence of biological activity of Dasanit in soil was similar to that of aldrin. Analysis by GLC indicated that Dasanit degraded in soil to Dasanit sulfone (0,0-diethyl 0-[p-(methylsulfonyl) phenyl phosphorothioate) which was insecticidally active and more persistent than Dasanit. Insecticidal activity of both compounds was dependent on soil and climatic conditions. Rutabagas grown in soil treated with Dasanit did not contain significant residues. Laboratory and field studies indicated that Dasanit was toxic to some beneficial soil arthropods and to earthworms, but did not significantly influence microbial activities in soil. It was concluded that many of the newer organophosphorus and carbamate insecticides may have deleterious ecological side-effects in soil and that, while these compounds will continue to have a major role in soil pest management programs, guidelines for registration should be devised to insure that these compounds be used in such a way to cause a minimum of side-effects in the soil ecosystem.

* * * * * *

Introduction

Recently there has been much criticism of the use of chemicals for insect control, because of adverse ecological side-effects. The organochlorine insecticides have been designated as the most ecologically hazardous and governments in several countries have restricted or eliminated their use. Concern over the environmental side-effects caused by some of these insecticides is justified. However, it is often assumed that the "less persistent" substitutes will not cause equally serious environmental side-effects. Actually, there is only limited knowledge of the potential ecological hazards of the newer pesticides, and the assumption that they will be less hazardous may be highly questionable.

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[1]Contribution no. 529, Research Institute, Canada Department of Agriculture, London 72, Ontario.

[2]Presented by the senior author as part of a Symposium entitled "Guidelines for Environmental Studies of Pesticides," Division of Pesticide Chemistry, American Chemical Society, Washington, D.C., September 13-17, 1971.

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With the benefit of hindsight, it is apparent that, to avoid the ecological disruption caused by DDT and some other organochlorine insecticides, we must, in future, insure that sufficient research on ecological side-effects can be completed prior to registration of an insecticide, or, at the very least, its introduction on a large scale. In some ways this would seem to be an impossible task. Almost any chemical when injected into the environment, in sufficient amounts, will have some deleterious effects. To ascertain all of these side-effects would be physically and financially prohibitive. Nevertheless, it should be possible to devise some general guidelines for environmental studies of insecticides utilizing certain indicators for measurement of potential environmental damage.

Insecticides and the Soil Ecosystem

Because insecticides are often applied directly to the soil for insect control or wash into the soil from treated foliage considerable attention has been paid to their effects in the soil ecosystem. Prior to registration of an insecticide, many questions must be answered with regard to its behaviour in soil. How long does it persist, and to what is it metabolized? Is the residue absorbed and metabolized in plants? Do soil inhabiting animals accumulate the residue which will then magnify up through the biological food chain? Is the residue in soil transferred to the aquatic ecosystem? Thus, great emphasis is placed on assessment of the *indirect effects* of insecticide residues in soil, as they move to air, water, wildlife, or into plants. In addition, the top few inches of the soil contain vast numbers of beneficial living organisms which contribute to its structure, formation, and fertility. Earthworms are of major importance since they break down much of the plant debris and aerate the soil. Many soil arthropods such as the wood lice, millipedes, centipedes, oribatid mites and several species of insects are also beneficial in that they also contribute to the disintegration and digestion of plant residues, and the breakdown of debris into the organic and inorganic constituents. Further down the biological chain microorganisms metabolize both organic and inorganic constituents in soil to forms acceptable for use by plants. Without the benefit of this biological cycle, soil structure and fertility would be seriously impaired. The soil also harbours, at some stage in their life cycle, many of the predators, parasites, and diseases which assist in keeping insect populations under control. Thus, we cannot afford to inject into this system, chemicals which will have *direct effects* on the soil ecosystem.

In North America research emphasis has been largely on the indirect effects of insecticide residues in soil. Fortunately, work has been initiated elsewhere to determine the direct effects which pesticides have on the soil ecosystem, particularly with regard to the effects of the organochlorine insecticides on non-target soil animals. Generally speaking it has been shown that most organochlorine insecticides, with exception of heptachlor and chlordane do not seriously deplete earthworm populations. However, these insecticides, particularly the cyclodienes, drastically altered populations of beneficial soil arthropods both in terms of biomass and numbers of species. DDT was less drastic in action, and in fact, resulted in an increase in beneficial arthropod weights (Edwards, 1969). Less is known about the effects of the organochlorine insecticides on soil microorganisms, although several studies (Bollen, 1961; Eno and Everett, 1958; Jones, 1956; Martin et al., 1959) have indicated that they have had little effect on microbial activities in soil.

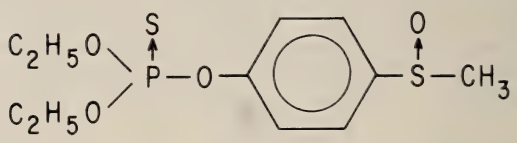
Some work has been done on the "early" organophosphorus insecticides, i.e. those compounds introduced in the late 1950's and early 1960's, such as diazinon, parathion, phorate, and disulfoton. Edwards (1969) has found that they as well as

one more recently introduced, chlorfenvinphos, have, with exception of phorate, little effect on earthworm populations. In addition, none affected the number of species or biomass of beneficial soil arthropod populations to the same extent as the cyclodiene insecticides. It also appears that the majority of these short residual compounds do not have any permanent deleterious effects on total soil microbial populations nor on such key factors as amonification, nitrification, or sulfur oxidation (Tu, 1970). None the less the possibility of more specific effects on soil microorganisms should not be discounted.

These studies have been done on insecticides which have been in use for many years and, in general, they were done after introduction of the insecticide. Use of some of these insecticides is now restricted, while others are rapidly being replaced by new compounds providing more effective insect control. Many new compounds have been introduced during the past 5 or 6 years, on which there is a paucity of information on ecological side-effects in soil. Several of these compounds are broad spectrum, moderately residual organophosphorus and carbamate insecticides (Harris, 1969), which will probably receive very extensive use.

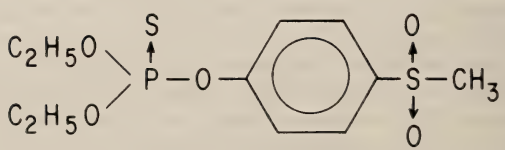
The effects which some of these new organophosphorus and carbamate insecticides can have on the soil ecosystem can be best illustrated by reference to one compound, Dasanit® or fensulfothion (Figure 1). The data presented here represent a summary of some of our recently published articles (Harris, 1969; Thompson, 1971; Tu, 1972) as well as unpublished work not yet completed.

DASANIT (FENSULFOTHION)



0,0-diethyl O-[p-(methylsulfinyl)phenyl] phosphorothioate

DASANIT SULFONE



0,0-diethyl O-[p-(methylsulfonyl)phenyl] phosphorothioate

FIGURE 1. Structure of Dasanit and Dasanit sulfone.

Registered Uses of Dasanit for Insect and Nematode Control

Dasanit is an organophosphorus insecticide-nematocide which was registered in Canada in 1965 for control of nematodes on ornamentals and since has been registered for a number of agricultural uses in Canada and the United States primarily for soil insect and nematode control (Table I). While the number of registrations is limited the crops involved could represent a large acreage. In Canada it was registered on a negligible residue basis. Recently the US established a tolerance of 0.1 ppm on rutabagas grown in Canada for export to the United States.

Table I. Registered Uses of Dasanit in the U.S.A. and Canada (1971).

Crops	Pests	Country
Corn	Rootworm	US, C.
Potato	Tuber flea beetle, wireworms	US, C.
Potato	Colorado potato beetle	C.
Crucifers	Cabbage maggot	C.
Onions	Onion maggot	US, C.
Peanuts	Southern corn rootworm, nematodes	US
Sugar beets	Sugar beet root maggot	US
Tobacco	Wireworms, nematodes	US
Tomatoes, sugar cane, turf	Nematodes	US
Ornamentals	Nematodes	US, C.

Persistence and Degradation of Dasanit in Soil

In our laboratory we routinely screen promising new insecticides to determine their activity in soil, including persistence of biological activity (Harris, 1969). These tests are run utilizing standard insecticides such as DDT which is highly, aldrin which is moderately, and diazinon, which is slightly persistent in soil (Figure 2). Tests with Dasanit indicated that it is moderately persistent in soil, with biological activity disappearing just a little more quickly than aldrin. However, while aldrin and diazinon yielded typical persistence curves, the results obtained with Dasanit were peculiar in that biological activity persisted at a very high level during the first 4 weeks after treatment, followed by a rapid drop-off in activity during the next 4 weeks. Subsequent studies using both bioassay and analysis by GLC indicated that Dasanit was degrading rapidly in soil (Figure 3) to Dasanit sulfone (Figure 1) which was also insecticidally active. In mineral soil Dasanit disappeared relatively quickly accompanied by a corresponding increase in sulfone. Biological activity persisted at a high level because of the joint action of the 2 compounds. Dasanit was the most insecticidally active. After 20 weeks, biological activity had dropped almost to zero, the amount of Dasanit present in the soil as Dasanit was approximately 3% of the initial application, while the sulfone amounted to approximately 38% of the initial Dasanit application. After 32 weeks, all biological activity had disappeared while the residue levels were more or less the same. In soil high in organic matter Dasanit was also converted rapidly to the sulfone (Figure 4). However, because of the pronounced effect which soil organic matter has on the biological activity of insecticides (Harris, 1972), no toxicity occurred in any of the bioassays. In the Canadian registration applications for

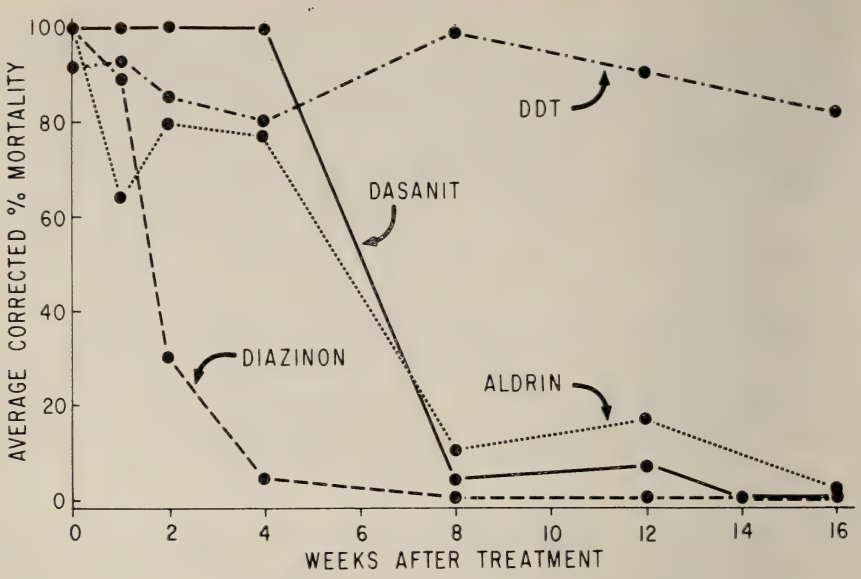


FIGURE 2. Persistence of biological activity under laboratory conditions of Dasanit as compared to diazinon, aldrin, and DDT (Test insects = 1st instar crickets, *Acheta pennsylvanicus* Burmeister).

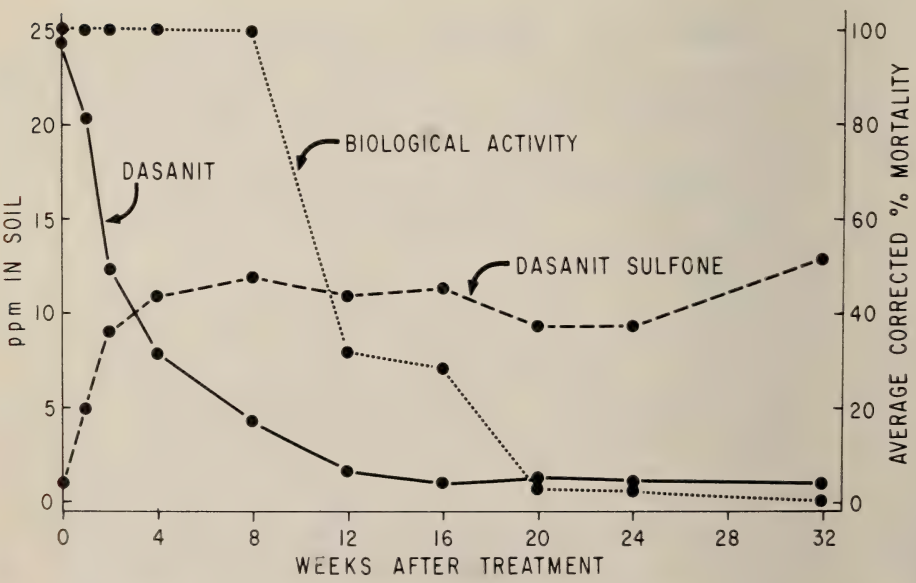


FIGURE 3. Persistence of Dasanit in Plainfield sand and degradation to Dasanit sulfone in relation to biological activity (Test insects = *A. pennsylvanicus*).

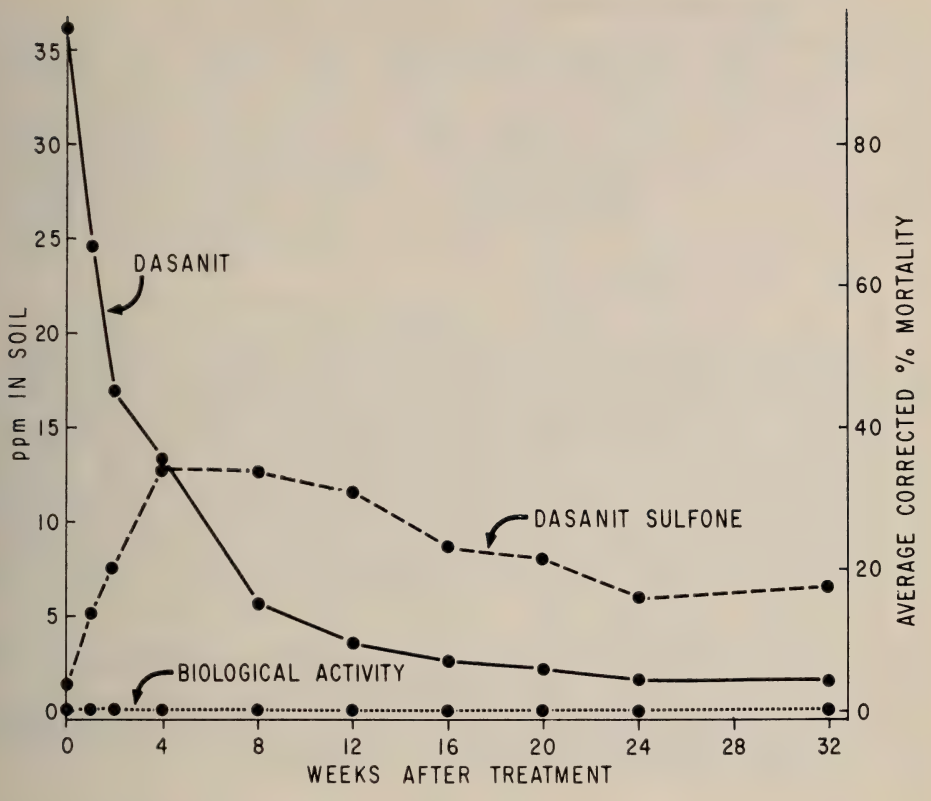


FIGURE 4. Persistence of Dasanit in muck soil and degradation to Dasanit sulfone in relation to biological activity (Test insects = *A. pennsylvanicus*).

Dasanit, there were some references to residues of Dasanit sulfone in plants. However, there was no information on Dasanit sulfone residues in soil. This data illustrates the need for provision of both biological and chemical data on the persistence of insecticide residues in the soil. Often a degradation product may be entirely overlooked if it is not picked up by standard chemical procedures of analysis. Bioassay can be used as a very useful tool to provide additional information.

Factors Influencing Insecticidal Activity of Dasanit and Dasanit Sulfone in Soil

Further studies were conducted to determine the relative insecticidal activity of Dasanit and the sulfone (Table II). As a direct contact poison, using first-instar nymphs of the common field cricket as test insects, the sulfone with an LD_{50} of 0.0024% was significantly more toxic than Dasanit which had an LD_{50} of 0.0031%. In mineral soil the reverse was the case and Dasanit was approximately twice as toxic as the sulfone. These results indicate that the sulfone is more strongly adsorbed and inactivated in mineral soil than Dasanit under the conditions of this test.

TABLE II. Insecticidal toxicity* of Dasanit and Dasanit sulfone

Insecticide	Method of Application	LD_{50}
Dasanit	Direct contact	0.0031%
D. sulfone	Direct contact	0.0024%
Dasanit	Soil treatment	7.66 ppm
D. sulfone	Soil treatment	16.45 ppm

*Test insects = 24-48 hr. cricket nymphs

Subsequent studies indicated some interesting differences in behaviour of the 2 compounds in soil in relation to such factors as type, moisture, and temperature (Table III). Tests on their activity in mineral and muck soil indicated, that as with all insecticides, soil type, particularly organic content, had a pronounced influence on bioactivity. Dasanit was strongly inactivated in muck soil and was 1/22 as effective as in the sand. The sulfone was less strongly inactivated in the organic soil and was 1/12 as effective as in the sand. Soil moisture also influenced toxicity, but to a lesser extent than soil type (Table III). Comparison of LD_{50} values for the sand at approximate field moisture capacity, and air-dry soil indicated that Dasanit was 3.4 times as effective in the moist as compared to the dry soil. By contrast, soil moisture had no significant effect on the toxicity of Dasanit sulfone at the 2 moisture levels tested. Activity of both compounds was also influenced by soil temperature (Table III), with the greatest effect on the sulfone. Dasanit was 7.7 x as effective at 33 as compared to 15°C, the sulfone was 14.4 x as effective. At the higher temperature the sulfone was almost equitoxic to Dasanit, while at the lower temperature, it was only 1/3 as effective.

TABLE III. Influence of soil and climatic factors on the biological activity* of Dasanit and Dasanit sulfone in soil

Insecticide	Soil			LD_{50} (ppm)
	Type	Moisture (%W)	Temperature C°	
		Soil Type		
Dasanit	Sand	5**	27	7.7
	Muck	117**	27	168.
D. sulfone	Sand	5	27	16.5
	Muck	117	27	197.
		Soil Moisture		
Dasanit	Sand	5	27	7.7
	Sand	0.5	27	25.8
D. sulfone	Sand	5	27	16.5
	Sand	0.5	27	18.7
		Soil Temperature		
Dasanit	Sand	5	15	43.
	Sand	5	33	5.6
D. sulfone	Sand	5	15	112.
	Sand	5	33	7.8

*Test insects = 24 to 48 hr. old cricket nymphs

**Approximate field moisture capacity

The data thus far have indicated that Dasanit, when applied to soil is a relatively short-residual compound which is rapidly converted to a more persistent metabolite, Dasanit sulfone. The sulfone is insecticidal, although it is generally less active in soil than the parent material. The biological activity of both compounds is dependent on soil type, temperature, and moisture, and under certain conditions of low temperature or dry soil the sulfone becomes as or more biologically active than Dasanit. Obviously, in so far as insect control is concerned, the effectiveness of "Dasanit" as a soil insecticide is dependent on the combined joint action of both compounds.

Absorption of Residues of Dasanit and Dasanit Sulfone by Plants

Information obtained to date on the absorption of residues of Dasanit and its sulfone by crops is fragmentary. In Canada, one of the major uses of Dasanit is for control of cabbage maggot attacking turnips. Residue data obtained on turnips treated with Dasanit according to one Canadian registration indicated no detectable residues of Dasanit either in roots or tops (Table IV). Residues of 0.007 ppm of the sulfone were detected in the roots, i.e. less than 1/10 the US tolerance of 0.1 ppm, while the tops contained 0.012 ppm of the sulfone. Thus, in the case of turnips, it appears that the recommended insect control program will not result in unacceptable levels of Dasanit and its sulfone in the crop.

TABLE IV. Insecticide residues found in turnips after using Dasanit as registered in Canada for cabbage maggot control.

Treatment	Residues* at harvest (ppm)			
	Dasanit		D. sulfone	
	Roots	Tops	Roots	Tops
Furrow + 2 drenches	N.D.	N.D.	0.007**	0.012
Control	N.D.	N.D.	N.D.	N.D.

*Lower limits of detection of 0.08 ppm Dasanit, 0.004 ppm D. sulfone ppm calculated on basis of fresh wt. of crop.

**US tolerance 0.1 ppm.

Effect of Dasanit and Dasanit Sulfone on Non-Target Soil Animals and Microorganisms

What of other effects in the soil ecosystem? In the Canadian submissions for registration, information was provided on bird and fish toxicity, but no information was given on non-target soil organisms. During the past 3 years the effects of Dasanit on non-target soil organisms have been examined. Because of the complexity of the problem certain key soil organisms were utilized as indicators. These included earthworms, springtails, soil microorganisms and carabid beetles. Studies were conducted in both the laboratory and the field.

The effect of Dasanit on earthworms was determined in a field trial in a trefoil pasture with a high population of earthworms (Figure 5). Dasanit emulsifiable concentrate was applied as a surface application to plants cut to a height of 2-3 inches at a rate of 3 lbs. actual insecticide per acre. DDT was applied at 5

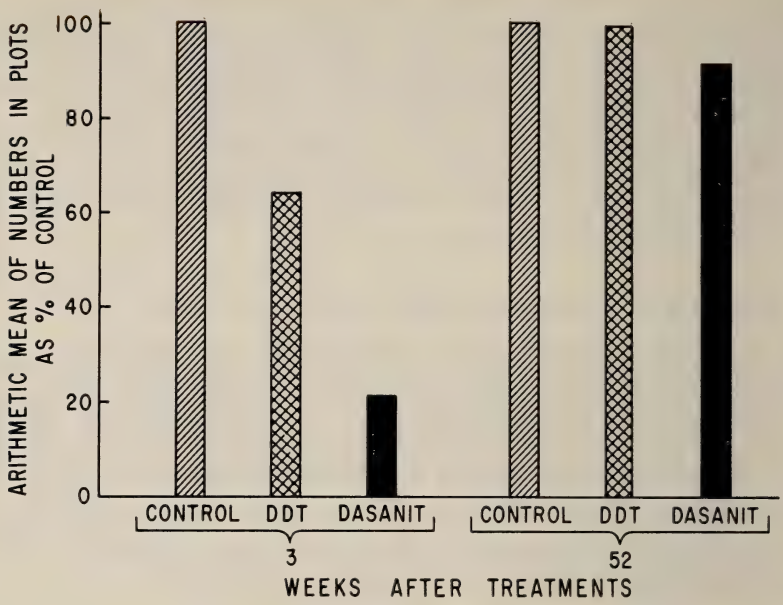


FIGURE 5. Effect of Dasanit and DDT applied at 3 and 5 lbs. a.i./acre respectively as surface applications to pasture on earthworms.

lbs. a.i./acre. There were 10 replicates of each treatment plus the untreated control. Three weeks after treatment the mean number of earthworms in the DDT plots was 64% of those in the control, statistically, not a significant reduction, in view of the fact that wide variations in earthworm numbers occurred in the various replicates. In the case of Dasanit, the arithmetic mean of number of earthworms in the plots was only 21% of the control population, a very significant reduction. Fifty-two weeks after the initial treatment, earthworm populations had recovered to normal in both the Dasanit and DDT treated plots. Residues of DDT found in the surviving worms were very high, with the mean residue being 128 ppm DDT and its metabolites three weeks after treatment. Worms surviving the Dasanit treatment contained residues of 0.25 and 22.52 ppm, Dasanit and Dasanit sulfone respectively. Fifty-two weeks after treatment, residues of DDT and its metabolites in the earthworms had declined to 8 ppm while no residues of Dasanit or its sulfone were detected.

Laboratory studies also indicated that Dasanit was more toxic than DDT to a common springtail occurring in soil, *Folsomia candida* (Table V). At 0.5 ppm Dasanit caused 100% mortality. By contrast, DDT caused only 5% mortality, even at a concentration of 50 ppm in soil. In other words, Dasanit was 100 x as toxic as DDT to this particular species of Collembola. Since there are many other species of Collembola occurring in soil which might show different tolerances to insecticides, a field trial was conducted to determine the effect of Dasanit on the total Collembola population (Figure 6). DDT as a surface application at 5 lbs. a.i./acre resulted in an increase in total Collembola over the control. In part this increase was due to the low toxicity of DDT to Collembola. In addition DDT is relatively toxic to predatory mites which prey on Collembola. By suppressing the predatory mites with DDT, the Collembola populations increased. By contrast,

TABLE V. Toxicity of soil applications of Dasanit and DDT to *F. candida* under laboratory conditions.

Inecticide	Av. Corr. % Mortality at indicated ppm in mineral soil				
	0.005	0.05	0.5	5	50
Dasanit	0	0	100	100	100
DDT	0	0	0	0	5

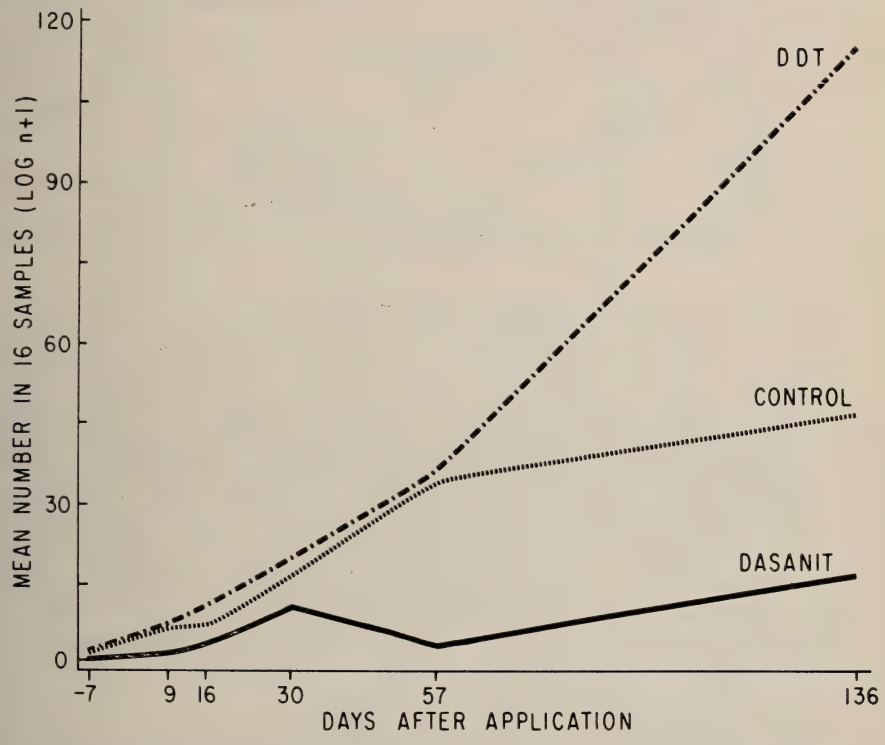


FIGURE 6. Effect of Dasanit and DDT applied at 3 and 5 lb. a.i./acre respectively on populations of Collembola.

Dasanit at 3 lbs. a.i./acre caused a marked decrease in the total Collembola population which persisted throughout the entire growing season. Sixteen weeks after the original treatment only 2% of the original Dasanit application was present, in the form of sulfone, i.e. 0.04 ppm, but this concentration appeared to be sufficient to suppress the Collembola population. This study is not yet complete and further samples are being taken to determine if the insecticide has any effect on Collembola populations 1-1½ years after application. However, it is apparent that, under certain conditions, Dasanit in the first year after treatment, can seriously deplete populations of soil animals of importance in maintaining soil fertility.

Laboratory tests on the effect of Dasanit on soil microorganisms (Figure 7) indicated that it had no significant qualitative effect on populations of bacteria or

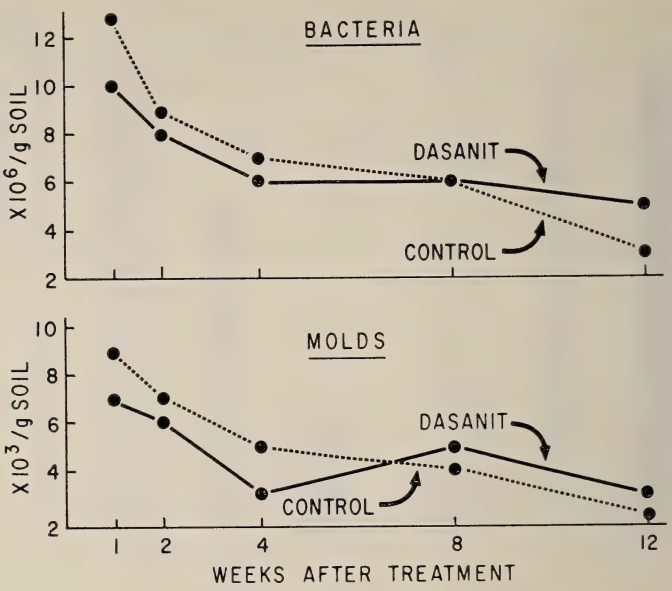


FIGURE 7. Effect of Dasanit on soil microorganisms.

molds in soils. Initially there appeared to be a slight depression as a result of the 5 ppm treatment but these differences were not statistically significant. Twelve weeks after treatment populations of both bacteria and molds in the Dasanit treated samples appeared to be greater than in the control soils. However, these differences were again not significant. Similar results have been obtained in field trials. No marked effects, occurred on microbial activities in mineral soil (Table VI). At a concentration of 1 ppm Dasanit there were no significant effects on ammonification, nitrification, or sulfur oxidation. At 5 ppm Dasanit appeared to have a slightly depressive effect on ammonification of added peptone nitrogen and on nitrification 2 weeks after treatment.

It is well known that carabid beetles are effective predators of dipterous eggs, and to a lesser extent the larvae and pupae. In Canada, Dasanit is registered and

TABLE VI. Effect of Dasanit on Microbial activities in a mineral soil.

Treatment (ppm)	Ammonification*		Nitrification* of ammonium from soil organic N		Oxidation* of elemental S
	Soil organic-N	Peptone N	1 wk.	2 wk.	
1	27	696	5	9	340
5	36	640**	5	10***	333
Control	36	688	5	7	397

*μg (NH_4+, NO_2—, NO_3—)—N, (NO_2—, NO_3—)—N, and SO_4=—S/g soil.
Significantly lower and * higher than control.

recommended for control of cabbage maggot, as is another organophosphorus insecticide, chlorfenvinphos. Both provide fairly effective cabbage maggot control and their persistence in soil is similar. Laboratory tests indicated that as a contact insecticide, Dasanit was approximately 10 x as toxic to *Stenolophus comma* and 100 x as toxic to *Bembidion quadrimaculatum* as chlorfenvinphos (Table VII).

TABLE VII. Direct contact toxicity of Dasanit and chlorfenvinphos to 2 species of carabid beetles

Species	Insecticide	Average Corrected % Mortality at indicated % solution			
		0.001	0.01	0.1	1.0
S. comma	Dasanit	0	100	100	100
	chlorfenvinphos	0	0	33	100
B. quadrimaculatum	Dasanit	0	100	100	100
	chlorfenvinphos	0	0	0	100

It is not the purpose of this paper to condemn Dasanit as an environmental pollutant. Rather, it has been used as an example to illustrate some of the effects which insecticides can have on the soil ecosystem, and to demonstrate that it cannot be assumed that simply because an insecticide is less residual it will have less deleterious ecological side-effects. The side-effects which will occur may be entirely different than those caused by the organochlorine insecticides. They may be confined more to the soil ecosystem rather than being transferred to the aquatic ecosystem. Because the materials are generally less persistent than the organochlorine insecticides, the side-effects may be more transitory. Nevertheless, before registering an insecticide for use on a large scale we should have information not only on efficacy and persistence of the insecticide in soil and uptake by crops, but on effects on beneficial non-target soil animals and microorganisms. Careful consideration should be given to limiting annual applications of these toxic compounds in situations where soil animals play an important role in maintaining soil fertility, e.g. in pastures, forests, or where no tillage techniques are followed. Studies should also be conducted to determine those insecticides which have the least deleterious effects on soil inhabiting predators and parasites. While chemical insecticides will certainly continue to have a major role in soil pest management programs, we must insure that they are utilized in such a way as to cause a minimum of environmental side-effects in the soil ecosystem.

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NEMATODE PARASITE OF THE FACE FLY IN ONTARIO

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Abstract

The nematode *Heterotylenchus autumnalis* Nickle, a parasite of the face fly *Musca autumnalis* DeGeer is reported for the first time from Canada. This nematode was widely distributed in Ontario in 1970-71, being found in flies from 20 separate sites. The incidence of infection was low; less than 2% of 19,297 flies. A slight increase in the nematode population was evident at four of five collecting locations in 1971.

* * * * * *

The nematode *Heterotylenchus autumnalis* (Nematoda: Sphaerulariidae), a parasite of the face fly *Musca autumnalis* was first reported as an undescribed species from New York in 1965 (Stoffolano and Nickle 1966) and subsequently named and described by Nickle (1967). There are currently six described species in the genus *Heterotylenchus,* all parasites of insects. Three species are reported from ground beetles in Germany, (Wachek 1955), one from fleas in Russia, (Kurochkin 1960), one from the onion maggot in Denmark, (Bovien 1937). In addition, *Heterotylenchus* sp. have been reported from *Morrellia hortorum* in Denmark, (Stoffolano 1969), the Australian bush fly *Musca vetutissima* (Hughes and Nicholas 1969) and the cabbage maggot *Hylemya brassicae* in Ontario (Nair and McEwen 1972). In addition, several species of muscoid flies in Nebraska are suspected as harbouring this genus (Jones and Perdue 1967).

Like other members of this genus, *H. autumnalis* has an alternation of gamogenetic and parthenogenetic generations. Nematode larvae from a parthenogenetic generation are deposited in cattle manure in the ovipositing activity of the host fly. These larvae mature, molt to adults and mate. The mated female, infective stage, enters a face fly larva, where she increases greatly in size and eventually lays eggs which give rise to parthenogenetic females. These lay many eggs which give rise to larvae that eventually invade the host ovaries and are deposited in cattle manure in place of the flies' eggs. All parasitic stages are found in the abdominal cavity of the host. Additional information on this nematode can be found in (Nickle 1967 and Stoffolano 1970a and 1970b).

Heterotylenchus autumnalis, like its host, is not endemic to North America (Stoffolano 1969), but it has been reported from face flies in several areas of North America (Jones and Perdue 1967, Nickle 1967, Stoffolano 1968, Treece and Miller 1968, Thomas and Puttler 1970, and Nickle personal commmunication). Thomas and Puttler (1970) suggest that *Heterotylenchus autumnalis* may be a significant biotic factor in controlling the face fly, a pest of increasing importance in Ontario during the past three years. The purpose of this study was to determine the distribution and seasonal infection rate of this nematode in Ontario in order to asses its potential as a biotic control agent here.

Materials and Methods

Face flies from 20 sites in Ontario were examined for the presence of *H. autumnalis* in 1970-1971. Flies were collected with an insect net directly from cattle or a bloody board. Bloody boards consisted of two pieces of masonite 20" x 24", hinged at the top so they would stand as an inverted V. Cheesecloth pads, saturated with citrated bovine blood and attached to external sides of the boards served as the attractant. Flies were easily collected as they congregated on the pads when cattle gathered around the boards. Flies so collected were released into small cages (1 cu. ft.) for transportation to the laboratory. They were then collected into plastic vials by means of an auto vacuum cleaner and held for dissection.

Flies were stored alive in a refrigerator, if they were to be dissected within a week, or if a longer period was anticipated, in a preservative (2.5 ml formalin, 2 ml. glycerol, 95.5 ml. distilled water). This was adjusted to pH 7 with NaoH and a few drops of liquid soap added as a wetting agent. Flies were dissected and examined through a binocular microscope. Only the abdominal cavity and its contents were examined critically since all stages of the parasite occur in this area.

In addition to the general survey, five sites were selected for systematic sampling to compare the seasonal and yearly incidence of *H. autumnalis*. For this study, two farms near Rockwood, Ontario Agricultural College at Guelph and Elora, a farm north of Fergus and a farm south of Galt were selected. Weekly collections were made from June through September, at Elora, Guelph and Rockwood in 1970 and from the first appearance of flies on pastured cattle — May or June into September for all five locations in 1971. Weekly collections were made for 30 minutes or until well over 100 flies had been collected. In the former case, all flies were examined, while in the later 100 females and all males up to 50 were dissected. Collections at the other sites ranged between one and seven collections per site made mostly during July and August. Generally, 30 minute collections were made at these sites with over half of the flies examined for nematodes.

Results and Discussion

A total of 19,297 face flies were examined in 1970-71 with 285 of these infected with *Heterotylenchus autumnalis*. The parasite was found at all 20 collection sites, Figure 1. Twelve of these sites are some distance from Guelph and were represented by only 16 collections comprising 2,601 flies or 13% of the total flies examined. The nematode infection rates for these 12 sites are grouped as to area and presented in Table 1. The highest average infection rate was in Eastern Ontario, 3.9%, (range 3.2 - 5.0%) and the lowest in South-west Ontario, 1.2%, (range 0.5 - 3.1%).

FIGURE 1. Distribution of *H. autumnalis* in Ontario 1970-71.

The remaining 87% of the flies examined were collected from eight sites in the general vicinity of Guelph. Information concerning these sites, number of collections, flies examined and nematode infection rate is shown in Table 2. The total number of flies examined in 1970 and 1971 was almost the same although a few more collections were made in 1970. The incidence of *H. autumnalis* was low, 1.2% and 1.5% for 1970 and 1971 respectively, but did show an increase in 1971 at four of the five locations, (Table 2).

A comparison of monthly infection rates for these locations is shown in Table 3. The infection rate at Guelph was quite similar for both years. The infection rate at Rockwood was higher through most of 1971 and was comparable with that at Guelph. The incidence of the nematode at Elora and Fergus was consistently lower than that at Guelph and Rockwood, but did increase in 1971. Galt was the only area in which the nematode population decreased in 1971. Part of this decline might be attributed to sampling error, since only one-third as many flies were examined from Galt in 1970, but part of the decrease might have been associated with the low winter survival as reflected by the low spring infection rates. As was the case in Nebraska, (Jones and Perdue, 1967), the nematode

TABLE I. Infection rate of *H. autumnalis* in face flies from four areas of Ontario in 1970.

Area	No. of Sites[a]	No. of Colls.	FACE FLIES No. Exam.	FACE FLIES No. Infect.	FACE FLIES % Infect.
E. Ontario	4	4	614	24	3.9
Lake Simcoe	2	2	433	7	1.6
Bruce County	3	4[b]	776	23	3.0
S.W. Ontario	3	6[b]	782	9	1.2
Total	12	16	2605	63	2.4

[a]Collection sites are shown in Figure 1. E. Ontario sites: Franktown, Richmond, Eganville and Palmer Rapids; Bruce County sites: Dobbington, Kincardine and Wiarton.
[b]One and three collections in 1971 respectively.

TABLE II. Infection levels of *H. autumnalis* in face flies in the Guelph area 1970-71.

Location	FACE FLIES 1970 No. Coll.	No. Exam.	No. Infected	% Infect.	FACE FLIES 1971 No. Coll.	No. Exam.	No. Infected	% Infect.
Elora	14	1083	6	0.6	15	1500	16	1.1
Fergus	2	257	1	0.4	11	1146	12	1.0
Galt	6	598	14	2.3	15	1985	19	1.0
Guelph	32	2834*	46	1.6	20	2130	41	1.9
Rockwood	28	2679*	18	0.7	22	1982	41	2.1
Brantford	1	210	1	0.5	—	—	—	—
Maryhill	8	288	7	2.4	—	—	—	—
Total	90	7949	93	1.2	83	8743	129	1.5

*Flies collected from 2 separate, but approximate sites.

TABLE III. Monthly infection rate of *H. autumnalis* in face flies in the Guelph area, 1970-71.

Location	Yr.	May	June	July	Aug.	Sept.	Total %
Guelph	1970	2.6[a]	2.2	1.5	1.3	1.9	1.6
	1971	2.1	2.4	1.3	1.3	2.2	1.9
Rockwood	1970	—[b]	1.6	0.1	0.7	0.7	0.7
	1971	3.3	1.1	1.7	2.0	2.4	2.1
Elora	1970	—	1.1	0.8	0.2	0.0[a]	0.5
	1971	—	2.7	0.7	0.4	1.1	1.1
Fergus	1971[c]	—	1.6	0.9	0.5	2.3	1.0
Galt	1970	—	2.6[a]	1.4	4.0	2.3	2.3
	1971	1.0	0.8	1.0	1.4	0.0	1.0

[a]Less than 100 flies dissected.
[b](—) No flies collected, generally because no cattle were on pasture.
[c]Only 2 collections, (Aug.) were made at Fergus in 1970. (Table 2).

showed a slightly increased infection rate in September, when a segment of the fly population would be entering the overwintering condition. Generally the lowest level of infection occurred in July and August, when the fly populations were at their peak.

In an attempt to relate the parasite and host activity, the 1971 (May through September) weekly population fluctuations of both species at Guelph and Rockwood are evaluated and presented in Figure 2. The bottom section portrays the weekly percent nematode infection, while the top section indicates the actual number of flies examined per week, not the estimated number of flies per animal. Flies were first found on cattle during the first week of May and were abundant for two weeks, but decreased rapidly in the third week. The population remained low from the third week to the sixth and seventh weeks when the first new brood of flies appeared at Guelph and Rockwood respectively.

The nematode infection rate during the first two weeks of May (the overwintered population) ranged between 2% and 4%, with all three nematode stages present in the infected flies. No nematodes were found at Guelph during the five weeks from three to eight, but it should be noted that the number of flies examined during this period was extremely low. This was also the case at Rockwood except that during the fourth week at Rockwood three of thirty-one flies were infected. This 9.7% infection rate was the highest of the year and although it involved only three infected flies, it is important to note that some of the last surviving overwintered flies are capable of transmitting nematodes to the new fly generation.

Nematodes reappeared in the eighth week with a 3.0 and 3.6% incidence. This represented a one and two week lag period between the appearance of the new fly generation and the appearance of the first infected flies. It would thus appear that although the face flies that were active the first week of May contained all three stages of nematodes, the larval forms had not yet developed to the infective stage or that infected flies did not attempt to oviposit. One must assume that no infective larval nematodes were deposited until sometime in the second week of oviposition. Thus the earliest host larvae were not exposed to the nematode explaining the absence of nematodes in the adults from these larvae.

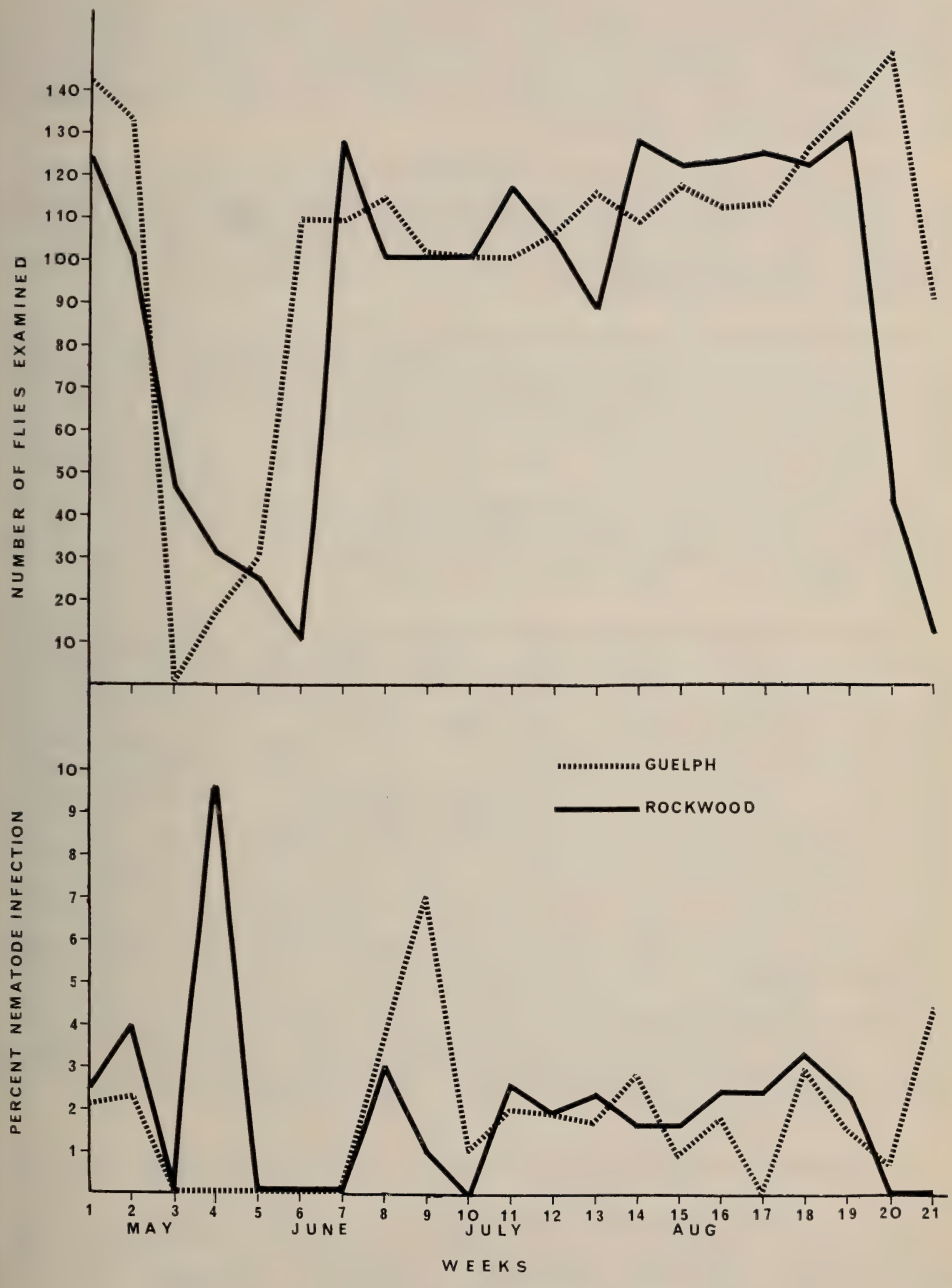

FIGURE 2. Seasonal fluctuations of nematode and face flies 1971. Weeks 1-6, 30 minute collections, weeks 7-20, 100 + flies collected in 30 minutes or less. (Weeks 7-10 est. less than 20 flies per face, weeks 11-20 est. 20-50 flies per face).

Flies were abundant from the seventh week on, with an estimate of less than 20 flies per face of each animal from week seven to eleven and an estimate of over 20 flies per face from week eleven to eighteen. The overall fly population decreased slightly during the ninth and tenth weeks, (not evident in Figure 2), probably due to some die-off of the first adults that emerged in weeks six and seven. These were quickly supplanted by the second brood of flies in week eleven, with continual emergence thereafter.

During weeks eight, nine and ten, the incidence of the nematode fluctuated widely with the highest infection rate of the year being achieved at Guelph in week nine. From weeks eleven to nineteen, the infection ranged between 1% and 3% at both sites, but dropped below this level in weeks twenty and twenty-one, except for one Guelph collection.

The incidence of *H. autumnalis* in Ontario in 1970-71 was much lower than that reported from United States face fly populations from 1965 to 1968 although similar sampling and collecting techniques were used. Stoffolano and Nickle (1966) reported a 23% infection rate in face flies from 14 counties in New York and a 6% rate in flies from 26 counties of six other New England states, (Stoffolano 1968). In Nebraska, Jones and Perdue (1967) reported a seasonal infection rate of 22% and 32% in flies collected as adults and those reared from larvae respectively. A study of Missouri flies collected from manure in 1968, revealed a 40% infection level, even though the fly population was low, (Thomas and Puttler 1970).

The low incidence of parasitism in this study plus suggestions that the true infectivity level of this nematode might be more representative in flies found on fresh cattle manure, i.e. flies needing to oviposit, prompted us to compare the infection rate of flies collected from manure with those collected from bloody boards and cattle. Seven collections of flies visiting manure were made during weeks eleven through sixteen at Guelph and Rockwood. Of 539 flies examined 24 or 4.5% were infected. During the same period, 1,342 flies were examined from the bloody board collections with 26 or 1.9% of these infected. This indicates a somewhat greater than two-fold increase of infected flies on manure, but it should be noted that almost half (12) of the infected flies from the bloody boards contained the infective nematode stages. It is probable that the nematode infection rate is higher in flies collected from manure, but I do not feel that such collections would give an accurate indication of the infection rate in the entire population. Theoretically at least, the non-infected flies should be visiting the manure for only the short period of time they are ovipositing, while infected flies with their ovaries full of larval nematodes might remain on the manure longer, unable to satisfy their ovipositional urge. Thus, sampling from manure only, would not adequately sample the non-infected portion of the population.

It is difficult to determine the reasons for the low incidence of *H. autumnalis* in Ontario as compared to populations elsewhere. Certainly, the face fly was in Ontario at an early date (Teskey 1960, 1969) and it would not seem feasible to suggest that this nematode had only recently established itself here. Perhaps, the recent increase in face flies, 1969-1971, as compared to population decline of the mid 1960's, has progressed much faster than that of the nematode. Continued yearly surveys for *H. autumnalis* should indicate if the slight 1971 increase continues. Certainly, if the yearly incidence remains similar to that of 1970-71, then this parasite will not contribute significantly to the natural control of face flies in Ontario.

Acknowledgements

I would like to express my appreciation to Dr. W. R. Nickle, Research Nematologist, U.S.D.A. Crops Protection Research Branch for confirming the identity of this nematode. This research was supported in part by N.R.C. Grant No. A6140.

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III. ERRATUM

In the paper by C. C. Loan "Two new parasites of the tarnished plant bug in Ontario : *Leiophron pseudopallipes* and *Euphoriana lygivora* (Hymenoptera : Braconidae, Euphorinae)" in volume 100 (1969) of the Proceedings of the Entomological Society of Ontario, pages 188 to 195, gender signs (♂. ♀) were omitted from the table on page 191.

The corrected table, with gender signs added, is included herewith:

	pseudopallipes			*pallipes*		
	N	Mean	SE	N	Mean	SE
Parameres of						
phallus length	25	0.204	0.0020	25	0.183	0.0020
basal width	25	0.183	0.0034	25	0.162	0.0038
Stigma						
length (♀, ♂)	46	0.461	0.0043	49	0.499	0.0074
Nervellus						
length (♀, ♂)	27	0.120	0.0021	44	0.30	0.0026
Basella length of						
basal abscissa (♀, ♂)	29	0.133	0.0024	45	0.148	0.0023
apical abscissa (♀, ♂)	29	0.155	0.0029	44	0.167	0.0025
Flagellum						
length (♂)	31	2.26	0.0314	20	2.41	0.0441
(♀)	36	1.84	0.0258	28	2.05	0.0299
no. segments (♂)	25	22.00	0.0577	25	23.12	0.1779
(♀)	25	19.12	0.1224	25	21.12	0.1868

IV. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND EIGHTH ANNUAL MEETING — ENTOMOLOGICAL SOCIETY OF ONTARIO

OTTAWA, ONTARIO

OCTOBER 6-8, 1971

Registration for the meetings was held from 10:00 to 12:00 a.m. on October 6 in Room 165, Sir John Carling Building, Central Experimental Farm.

MEETING OF OUTGOING DIRECTORS

The 1970-71 Board of Directors met on October 6, 1971, in Room 750, Sir John Carling Building at 9:00 a.m. Those present were President C. R. Sullivan, Past President S. E. Dixon, Directors R. E. Bellamy, J. A. George, R. J. McClanahan and H. J. Teskey, and Secretary-Treasurer D. H. Pengelly. Vice-President R. L. Edwards and Director P. J. Pointing were absent.

President Sullivan called the meeting to order at 9:25 a.m.

The minutes of the Directors' Meeting held at Vineland November 6, 1970 were accepted as circulated on a motion by D. H. Pengelly, seconded by H. J. Teskey.

Secretary-Treasurer's Report

The Secretary-Treasurer provided the Financial Statement for the year ending December 31, 1970. This was accepted for presentation at the Annual Meeting on a motion by R. E. Bellamy, seconded by R. J. McClanahan. The Interim Financial Statement for the period ending September 30, 1971 was presented and accepted on a motion by S. E. Dixon, seconded by J. A. George. The Directors, on a motion by R. J. McClanahan seconded by H. J. Teskey instructed the Secretary-Treasurer to purchase $2,000.00 worth of Canada Savings Bonds, 1971. The Secretary-Treasurer was instructed to contact Mrs. Ketemer on the costs for reprints.

The results of the mail ballots were made known to the Directors. The Secretary-Treasurer reported that for the first time a tie-vote of significance occurred. There being no means within the constitution to break such votes, it was done by the Scrutineers in a fair way.

Editor's Report

The report of the Editor was amended and approved on a motion by S. E. Dixon calling for the deletion of three words " . . . and other entomologists" in paragraph three. The motion was seconded by R. E. Bellamy. The Directors were unanimous in their outline of advantages of being a Society member and free publication should not be extended to all entomologists. Motion carried.

Library Committee

It was announced that an oral report will be given at the annual meeting.

Report of Representative on Common Names

The report was accepted for presentation to the annual meeting. The Directors asked if a letter from the Society would help in getting some action in the E.S.A. No decision was reached at this time.

Promotion of Entomology in High Schools

P. J. Pointing was unable to attend and a verbal report will be presented by the President. It was suggested that a hand-out of supplies of entomological equipment be compiled. Members should be encouraged to submit slides to the committee chairman.

Implementation of Pesticide Regulatory Board

No progress report to be presented.

Collection of Dues

A committee chaired by C. R. Sullivan presented a report. A motion that the Entomological Society of Ontario continue to be responsible for the collection of its own dues was made by S. E. Dixon and seconded by J. A. George. After considerable discussion on the merits and disadvantages the Directors were unanimous in approving the motion. The membership will be informed.

Committee on Honourary Membership

No action was possible other than a recommendation because of the existing By-laws. It was moved by S. E. Dixon that a committee on By-laws be formed to review, up-date and recommend changes to allow the re-establishment of a membership category which would include the Committee recommendation; seconded by H. J. Teskey. Motion carried.

President's Prize Committee

A form for use and modification by the judges was made available for this meeting.

New Business

The Entomological Society of Canada requested that the Ontario Society send available volumes of the Proceedings to their archivist. The Secretary-Treasurer was instructed to forward these.

The meeting adjourned at 11:40 a.m.

Registration continued from 1:00 to 3:00 p.m. in Room 165.

Annual Meeting

The 108th Annual Meeting was held in Room 165. The opening session began at 1:15 p.m., October 6, under the chairmanship of President C. R. Sullivan. An address of welcome was given by Dr. W. B. Mountain, Director, Entomology Research Institute, Ottawa. An address by President Sullivan included announcements about the upcoming session.

Four papers were presented under the chairmanship of J. A. Downes at a session starting at 2:00 p.m.

Griffiths, K. J. (Sault Ste. Marie). Discrimination between parasitized and unparasitized hosts by *Pleolophus basizonus* (Grav.).

Baldwin, W. F. and G. D. Chant (Chalk River). Field studies on dispersal and longevity of mosquitoes tagged with ^{32}P.

Miller, C. D. F. and J. C. Guppy (Harrow and Ottawa). Alfalfa weevil nemesis in Canada.

Elliott, W. M. (Harrow). A method of predicting population trends of the green peach aphid.

After a recess, a symposium on the relationship between biosystematics and applied entomology, under the chairmanship of W. R. M. Mason, Entmology Research Institute, Ottawa, was held with W. J. Turnock, Science Secretariat, Ottawa and G. E. Shewell, Entomology Research Institute, participating.

On Thursday morning, October 7, under the chairmanship of C. R. Sullivan, a session was held starting at 9:15 a.m., for presentation of papers in competition for the President's Prize by seven students.

Lerer, H. (University of Guelph). Female dimorphism in honey bee larvae with respect to glucose metabolism.

Gregory, D. (University of Guelph). Radiation sterilization of the face fly, *Musca autumnalis* DeGeer.

Latheef, M. A. (Carleton University). A quantitative study of food consumption and growth in *Leptinotarsa decemlineata* Say on potato and tomato.

Gross, H. (Queen's University). Variability in blackfly populations.

Lush, D. (University of Waterloo). Particulate food for insect larvae in streams.

Williams, D. D. (University of Waterloo). The vertical distribution of arthropods in stream beds.

Tolman, J. H. (University of Western Ontario). The role of ions in rectal function of the cockroach, *Periplaneta americana* (L.)

At 11:15 a.m., a session was held under the chairmanship of A. E. Downe for the presentation of papers.

Dixon, S. E. and T. P. Liu (Guelph). Corpus allatum activity during caste determination in honey bee larvae.

Shearer, D. A. and R. Boch (Ottawa). Chemical releasers of alarm behavior in the honey bee, *Apis mellifera.*

An evaluation of the activities of various esters, ketones, aldehydes, alcohols, ethers, and hydrocarbons on releasers of the alarm reaction in worker bees has shown the molecular weight, shape, and polarity of the substances to be important factors. The activities are highest with compounds which most closely resemble the natural alarm substances iso-pentyl acetate and 2-heptanone. The results will be discussed in the light of various theories of olfaction.

Corbet, P. S. and S. M. Smith (Waterloo). The diel periodicity of landing of parous and nulliparous *Aedes aegypti* (Diptera : Culicidae) at Dar-es-Salaam, Tanzania.

The periodicity of landing by female *Aedes aegypti* (L.) on human baits during three successive, 24-hour catches in suburban Dar-es-Salaam in April, 1971, was bimodal; the peaks of landing activity were closely associated with sunrise and sunset and activity was much lower at midday. Among the total number of females landing, there were no significant differences in the proportions of either inseminated or nulliparous females at different times of the day. These data suggest that sub-sampling to obtain population indices for the epidemiologically relevant portion of the population (parous females) can be carried out irrespective of suntime, permitting such assessments to be conducted, economically, during the hours of peak abundance.

Gochnauer, T. A. and S. J. Hughes (Ottawa) and J. Corner (Vernon). The isolation and identification of *Ascosphaera apis* from chalkboard disease honey bee larvae in Canada.

Kapoor, N. N. (Waterloo). A recording device for measuring respiratory movements of aquatic insects.

Singh, S. B. and P. C. Nigam (Halifax and Ottawa). Histochemical studies on the haemocytes of 5th-instar spruce budworm larvae.

Based upon histochemical and fine structural observations, the haemocytes of the 5th-instar spruce budworm larvae have been grouped into five different types: (1) Prohaemocytes, (2) Plasmatocytes, (3) Granular haemocytes, (4) Spheroidocytes, and (5) Oenocytoids.

(1) *Prohaemocytes:*

These are small non-phagocytic agranular spherical cells with basophil cytoplasm which forms a rim around the large vesicular central nucleus which contains a nucleolus. The cytoplasm contains a few strands of rough endoplasmic reticula; however, many free ribosomes and a few mitochondria which are evenly distributed throughout the cytoplasm are also seen.

(2) *Plasmatocytes:*

These are large, polymorphic, nonphagocytic cells with agranular basophil cytoplasm. The central vesicular nucleus is surrounded by a greater area of cytoplasm. A few cisternae of rough endoplasmic reticula with lots of free ribosomes which occur singly or as polyribosomes, are present in the cytoplasm along with a few mitochondria.

(3) *Granular haemocytes:*

These are medium sized polymorphic, phagocytic granular cells with an eccentric vesicular nucleus. The cytoplasm contains one to several granules of various sizes, which are sudanophilic. It also contains a few vacuoles and a few elongated cisternae of rough endoplasmic reticula, along with a few mitochondria.

(4) *Spheroidocytes:*

These are large cells of irregular shape, and contain a pyknotic nucleus which is small and round. The cytoplasm contains large vacuoles which are filled with some mucus-like substance. The cell is almost completely devoid of cytoplasmic organelles.

(5) *Oenocytoids:*

These are large caudate cells with a small, eccentric nucleus. The cytoplasm of the cell is quite basophilic because of ribosomes. An extensive network of smooth and rough endplasmic reticula are also seen in the cell cytoplasm. There are a few mitochondria which are evenly distributed throughout the cytoplasm.

The Annual Business Meeting of the Society was held at a session from 2:15 to 3:00 p.m. At 3:15 p.m. the session for presentation of papers was resumed.

WRIGHT, R. E. (Guelph). The face fly, *Musca autumnalis,* in Ontario: distribution, importance, control and occurrence of a nematode parasite.

MILLER, C. D. F. (Harrow), GAGE, S. AND D. HAYNES (East Lansing). Cereal leaf beetle studies in Canada. I. Within-generation mortality in artificially established populations.

The cereal leaf beetle is becoming an economically important insect in Canada. The identification of mortality within a generation of this insect is difficult, partly because of overlapping instars, due to the adults laying eggs throughout the entire developmental period, which in nature is from April to mid-June.

Adult cereal leaf beetles were placed in cages for three days at different times and at different densities on wheat and oats throughout the 1971 growing season. These layed a pulse of eggs on the caged plants and gave an even aged distribution of the four larval stages. Adults and cages were removed after the three-day period and the eggs and hatching larva were allowed to develop under natural conditions.

The cohort populations were sampled twice daily and recorded counts defined the shapes of the incidence curves of each of the instars. Analysis of the data afforded an accurate assessment of mortality within and between these life stages.

Such studies are not possible in areas where the cereal leaf beetle is abundant because of natural recruitment into established cohorts. The study technique in this reported experiment allowed us to accurately examine natural mortality of artificially established small populations of the cereal leaf beetle at different densities on wheat and oats through time within a single growing season.

HAYNES, D. (East Lansing) AND C. D. F. MILLER (Harrow). Cereal leaf beetle studies in Canada. II. Population increase in south-western Ontario.

An intensive survey-type study currently under way is obtaining quantitative data on population change of the cereal leaf beetle throughout its entire area of distribution in North America. The Canadian theatre of the study is an integral component of the research and reflects the provincial, national and international cooperative nature of the overall program. Participating personnel belong to the Canadian Department of Agriculture, Ontario Department of Agriculture and Food, Michigan State University and a number of state government agencies from states where the beetle occurs.

Estimated population densities calculated from data collected at six study sites in south-western Ontario has been determined and predicted population trends are suggested as far as possible with the limited available data.

The data from the entire survey forms a major input into a systems-analysis study on the C.L.B. currently conducted at Michigan State University. The overall study, though academic in nature, also has feasible, mission-oriented qualities.

Ivanochko, M. (Ottawa). An evaluation of some of the factors that may contribute to proliferation of braconid parasites.

Nair, K. S. S. and F. L. McEwen (Guelph). Biology of the cabbage maggot, *Hylemya brassicae* with some observations on a fungal and a nematode parasite.

Data on the population size of adults, eggs and larvae o the cabbage maggot, *Hylemya brassicae* Bousché on rutabagas were obtained from an experimental plot at Preston, Ontario during the 1970 and '71 seasons. Three generations occurred in this region, with a partial fourth in 1970, but the adult population size was about equal in each generation. Though varying in intensity, egg laying occurred throughout the season.

The staphylinid predator-parasite, *Aleochara bilineata* Gyll. also had three generations per year, the emergence of the adult parasit coinciding more or less with that of the host. However, the emergence of adults of the cynipid parasite, *Trybliographa rapae* West. from the first generation of *H. brassicae* pupae was considerably delayed, and moreover, only about 50 per cent of them emerged during the same year; thus *Trybliographa* had only one full generation and a partial second generation per year.

Data on the percentage of *H. brassicae* parasitised by these insects during each generation are given.

Parasitism of adult *H. brassicae* by a nematode of the genus *Heterotylenchus* and an unidentified fungus are recorded for the first time and observations on their effects and percentage parasitism are given.

On Thursday evening, October 7, a reception and banquet were held in the Talisman Motor Hotel at 6:30 p.m. The President's Prize was presented. The guest speaker was Dr. W. J. Morrison, Research Coordinator, Canada Department of Agriculture, Ottawa.

On Friday morning, October 8, starting at 9:15 a.m., a session was held, under the chairmanship of L. Manser, for the presentation of papers.

Wood, D. M. (Ottawa). Evolution of filter-feeding mouthparts of nematocerous Diptera.

Downes, J. A. (Ottawa). The biting midges (Diptera : Ceratopogonidae) as predators.

A number of well-known biting midges (e.g. *Culicoides, Forcipomyia, Leptoconops*) are blood-suckers on vertebrate or large insect hosts; but others, all in the subfamily Ceratopogoninae, feed on small insects. The hunting female enters the visually-determined mating swarm of insects such as Chironomidae, Culicidae, and various Ephemeroptera, and hovers there until in a position to make a quick strike and capture its prey; the prey, in consequence, is nearly always of the male sex. Sufficient examples are now known to indicate that this behaviour is typical of all groups of Ceratopogoninae other than *Culicoides* that occur in Canada — a total of 5 tribes containing some 17 genera.

Observations and experiments relating to finding the prey swarm, prey-capture, and the process of feeding are discussed. Mating, in these as in most other biting midges, also takes place in flight within a visually-determined swarm; and it appears that insome genera the female, entering her specific (mating) swarm, remains nevertheless in the hunting phase. Thus capture of the female by the male, as mate, coincides with capture of the male by the female as prey, and the female feeds on the male during mating.

Shewell, G. E. (Ottawa). On the larval hypostomium in Simuliidae (Diptera), with a tentative system for numbering the teeth.

Earnshaw, A. (Ste. Anne de Belluvue). Potential and actual prey in two sheetweb spiders (Araneida : Agelinidae).

Bracken, G. K. and M. Maw (Belleville). A field test of an autocidal control method applied to a non-isolated population of mosquitoes.

Nigam, P. C. (Ottawa). Evaluation of fenitrothion to protect the forest ecosystem from insect pest damage.

DDT was used until 1968 to protect the forests from insect damage but due to its ecological implications, a search for alternate insecticides was started in 1965. A number of insecticides are still under study but fenitrothion has replaced DDT in large scale operations. This paper describes the evaluation of fenitrothion carried out against 17 insect pests belonging to the orders Lepidoptera, Hymenoptera, Coleoptera, and Hemiptera, and against non-target components of the forest ecosystem. The non-target components studied are fish, birds, amphibians, and mammals; the residues of fenitrothion in air, soil, and plants are also discussed.

WALLACE, R. R. (Waterloo). Rhodamine B dye as an insecticide tracer in running waters.

MCCLANAHAN, R. J. AND J. FOUNK (Harrow). Control of the European corn borer in sweet corn and peppers in Southwestern Ontario.

A meeting of the incoming directors was held in Room 750, Sir John Carling Building, Central Experimental Farm, at 11:30 a.m.

ANNUAL BUSINESS MEETING

The Annual Business Meeting was held in Room 165, Sir John Carling Building. The meeting was called to order at 2:15 p.m., October 7, by President Sullivan, with 39 present.

The Society regrets the passing of a member, F. W. Gregory of Niagara Falls, in January, 1970. Notice of his death was not received until June, 1971.

The Secretary-Treasurer moved that the minutes of the 107th Annual Meeting be accepted as circulated. The motion, seconded by W. F. Baldwin, was passed.

The financial statement for the year ending December 31, 1970 was presented. A motion for its acceptance by S. E. Dixon, seconded by D. G. Peterson, was carried. (See Vol. 101 of the Proceedings, Appendix I).

The interim statement to September 30, 1971 was presented and a motion for its acceptance made by D. G. Peterson seconded by H. J. Teskey was accepted.

The mail ballot showed the following to be elected Directors for 1971-1972: W. C. Allan, R. E. Bellamy, R. W. Fisher, W. G. Friend, G. T. Harvey, R. J. McClanahan and H. J. Teskey.

George Pearson Holland was elected as a Fellow of the Entomological Society and is welcomed as the 8th member of this honoured group.

Membership in the Society as of September 30, 1971

Fellows	6
Life Members	2
Honourary	2
Regular	293
	303
not paid	20
	323

EDITOR'S REPORT

Volume 101 of the Proceedings has been printed as an issue of 106 pages and includes five reviews of infestations of insects and other pests, two invited papers, eleven submitted papers and the Proceedings of the 107th annual meeting held at Vineland, November 4 to 6, 1970.

The inclusion of an abstract of each published article, before the maine body of the article, has proved to aid considerably in the abstracting of the journal by BIOLOGICAL ABSTRACTS and other abstracting services.

Members of the Society are encouraged to submit papers on all branches of entomology, for Volume 102, in particular reviews of infestations and studies of insects in Ontario. Authors are requested to include an "Abstract" in the manuscript between the name and address of the author and the main body of the article, as in Volume 101, for use by BIOLOGICAL ABSTRACTS. Prepare papers according to the guide on the inside back cover of Volume 101, 1970, and submit them by January 15, 1972.

W. W. Judd
Editor.

The Report was accepted on a motion by C. D. F. Miller, seconded by E. H. Peters.

REPRESENTATIVE TO COMMON NAMES COMMITTEE

No proposals for common names were received by the E.S.C. Committee during the past year.

Some 65 names were submitted to the Entomological Society of America Committee last year by the ESC Committee. This unusually high number arose largely from Publication No. 424 of the Manitoba Department of Agriculture and Conservation: *Common Names of Insects and Mites Associated with Stored Products in Canada*. Approximately 60% of these names were approved by the ESA Committee. This is an extreme case of the existing situation that continues to challenge the objectivity of many entomologists in Canada. The ESA list of approved common names of insects has been accepted by the ESC as the standard for usage in Canada in the interest of achieving uniform usage in English-speaking North America. Names placed on that list are still, however, subject to the ultimate authority of an ESA Committee of nine members, of whom one is a Canadian, appointed by the ESA. The ESC has no official role in the approval of what has become the standard list of approved names for insects in North America.

The establishment of an ESA-ESC joint North American Committee on Common Names is still being pursued. ESC President Le Roux reported (Bull. Ent. Soc. Canada, 2(4):94, 1970): "I have been unsuccessful in my attempts, through correspondence with the President of the Entomological Society of America, to get agreement on the formation of an ESA-ESC joint North American Committee on common names. The Board is not satisfied with the present monolithic structure of the ESA Committee and has asked Dr. H. F. Madsen, a member of the Governing Board of the ESA to investigate delays on resistance on the part of the ESA Committee in the matter and no report to the ESC Board at the January 1971 meeting." No further word on the outcome of Dr. Madsen's investigation has reached the ESC Committee as of this date.

The most recent edition (1971) of the ESA publication *Common Names of Insects Approved by the Entomological Society of America* is now available. Copies are available from the ESA business office, no charge to ESA members, $2.00 to non-members.

Dr. Anne Hudson served as proxy ESO delegate at the meeting of the Common Names Committee held during the annual meeting of the ESC in Victoria.

Glenn B. Wiggins
ESO Representative
ESC Committee on Common
Names of Insects

C. D. F. Miller moved that this Report be accepted, seconded by G. T. Harvey; Carried.

LIBRARIAN'S REPORT

The exchange listing which was set up last year is working well and we are presently receiving 37 exchanges from 26 countries. In addition to the Canadian Entomologist Exchanges the Society sends 82 issues of the Proceedings to 27 different countries and received 32 publications in exchange.

The McLaughlin Library has catalogued all exchanges into the appropriate sections of the library and all are readily available on Library Loan.

W. C. Allan
Librarian.

Acceptance was moved by W. C. Allan, seconded by H. J. Teskey; Carried.

COMMITTEE ON PROMOTION OF ENTOMOLOGY IN ONTARIO SCHOOLS

President Sullivan gave a verbal report in the absence of P. J. Pointing on the progress being made in compiling sets of slides for use in schools.

PRESIDENT'S PRIZE COMMITTEE

A form to assist in judging the papers submitted in this competition was of the nature of a "trial balloon". Judges were invited to use it, make changes and suggest ways to implement a feed-back system of constructive criticism to the students.

COLLECTION OF DUES

The Directors approved of the Society continuing to be responsible for the collection of its own dues. The Secretary-Treasurer is to inform the membership and to continue in the role of an intermediary for members wishing to pay the Ontario and Canadian Society dues as in the past.

HONOURARY MEMBERSHIP

It is the recommendation of the Directors that a committee be formed to draft changes in the by-laws on Honourary Membership and get the approval of the Minister of Agriculture. The proposed changes will alter the Associate Membership or re-instate the Honourary Membership so that members of the Society, who at the time of their retirement wish to continue with all rights and privileges other than voting, can do so without paying dues. This committee is to be formed by the Directors.

NEW BUSINESS

R. J. McClanahan asked if the Society would express its approval of the International Organization of Biological Control by taking out an Institutional membership for $50.00.

After some discussion and clarification this was directed to the Incoming Board on a motion by S. E. Dixon, seconded by P. S. Corbet; Motion carried.

D. G. Peterson took exception to the "doom and gloom" attitude that seems to have enveloped the field of biosystematics. He stated that the Society should make a positive statement on the needs for service in biosystematics as environmental research proceeds.

He moved that the Board of Directors examine the feasibility and wisdom of issuing a public statement on our needs in biosystematics and ask the National Society to play an active part. G. F. Manson seconded the motion and from the discussion that followed it was evident that a Position Statement should include all entomological endeavors. The motion carried.

P. S. Corbet moved that the Entomological Society of Ontario endorse the expression of concern regarding the future support of Entomology in Canada as expressed by the President of the Entomological Society of Canada in Victoria in 1971. This motion was seconded by C. D. F. Miller and carried unanimously.

C. D. F. Miller raised the question of having a combined meeting with the North Central Branch of the Entomological Society of America somewhere in southwestern Ontario in the near future. A motion asking the Directors to consider this, made by C. D. F. Miller, seconded by D. G. Peterson, was carried.

The Society was invited by Dr. A. M. Marko through W. F. Baldwin to hold its 109th Annual Meeting at Chalk River. W. C. Allan moved that the Society accept this kind invitation, seconded by C. D. F. Miller. The acceptance of the motion was unanimous.

Appointment of Auditors

The Secretary-Treasurer reported that B. E. Saunders and associates had served as auditors in the past and moved that they be re-appointed. Ann Hudson seconded the motion. Carried.

Report of Resolutions Committee

1. WHEREAS the members of the Society have enjoyed the accommodations provided by the Canadian Department of Agriculture for holding of this, the 108th Annual Meeting,

BE IT RESOLVED that we extend to the Department our sincere thanks for its part in making these meetings a success.

2. WHEREAS the program of the meeting has been excellent in both the appropriateness of the general theme, "Systematists and the Applied Entomologists" and in the quality of the entire program, BE IT RESOLVED that we extend to the members of the local committee under the chairmanship of Dr. J. J. Cartier our sincere thanks for their efforts.

3. WHEREAS the invited speakers for the symposium on "The relationship between biosystematics and applied entomology" gave us much food for thought, BE IT RESOLVED that we extend our thanks to the Moderator Dr. W. R. Mason and to the speakers Dr. W. J. Turnock and Mr. G. E. Shewell for their contribution to the program.

4. WHEREAS the competition for the President's prize is a valuable means of stimulating the interest of students in the field of Entomology, BE IT RESOLVED that we extend our thanks to Dr. D. Oliver, Dr. G. Harvey and Dr. R. Byers for participating as judges.

C. D. F. Miller (Chairman)
K. J. Griffiths

K. J. Griffiths moved that the report be accepted, seconded by W. F. Baldwin; motion carried.

There being no further business the meeting was adjourned at 3:05 p.m.

MEETING OF INCOMING DIRECTORS

The meeting of incoming Directors for 1971-1972 was held in Room 750, Sir John Carling Building, October 8.

Present were C. R. Sullivan, W. C. Allan, R. E. Bellamy, G. T. Harvey, R. J. McClanahan, and H. J. Teskey. Abesnt were R. W. Fisher and W. G. Friend.

President Sullivan called the meeting to order at 11:30 a.m. and expressed his thanks to all concerned for the successful meetings. He then called for nominations for President of the Society.

H. J. Teskey was nominated but declined.

W. C. Allan was nominated by R. J. McClanahan.

G. T. Harvey moved nominations closed, R. J. McClanahan seconded; the motion carried.

President Allan assumed the chair as the Society's 57th President. Nominations for Vice-President were called and R. W. Fisher was nominated by H. J. Teskey, seconded by C. R. Sullivan. R. E. Bellamy moved nominations closed; the motion carried.

D. H. Pengelly was re-appointed as Secretary-Treasurer.

The minutes of the last Directors Meeting, held October 6, 1971, were read and a motion for their acceptance by the Secretary was seconded by R. E. Bellamy; motion carried.

Appointment of Committees

Library: W. C. Allan agreed to continue in his capacity of chairman of the committee; G. F. Townsend and M. V. Smith were to be asked to continue as members. W. C. Allan would continue to act as Librarian.

Editor: W. W. Judd was re-named Editor of the Proceedings of the Society on a motion by C. R. Sullivan, seconded by R. J. McClanahan. J. E. Steele and G. McLeod were re-named as members of the Editorial Committee.

Nominating Committee

The Board agreed that P. G. Fast be asked to chair this Committee which includes the Past President and the Secretary-Treasurer.

Scrutineers

S. E. Dixon and W. H. A. Wilde were named as Scrutineers.

Representative to the Entomological Society of Canada Committee on Common Names of Insects

G. B. Wiggins has served well in this capacity and is asked to continue.

Representative to the Committee for Electing Fellows to the E.S.C.

G. T. Harvey agreed to accept this appointment and also to act as Director-at-large to the Entomological Society of Canada for the 2-year term, 1971-1973.

Committee on the Constitution and By-Laws

G. T. Harvey was named as a Committee of one, with power to add, to review and revise the existing Constitution and By-laws for presentation to the members.

Committee on Combined Meetings

C. D. F. Miller was named as chairman of this investigation committee assisted by R. J. McClanahan. The committee has power to add. The time and place of a possible meeting with the North Central Branch of the Entomlogical Society of America are to be considered. The combining with the next joint meeting of the E.S.C. and the E.S.O. in 1976 was suggested as a possibility.

Public Relations

The President is to follow the directive from the Annual Meeting on the preparation of a position statement on the need for support in Entomology.

Committee on the Promotion of Entomology in Ontario Schools

P. J. Pointing was re-named to chair this committee and continue the programme already underway.

Approval of Expenditures

1. Auditors' fees, $10.00.
2. Secretary-Treasurer's Honorarium, $200.00.
3. Secretarial assistance, $25.00.
4. Allowance or help to move library holdings to another building.

Moved by C. R. Sullivan, Seconded by H. J. Teskey.

R. E. Bellamy amended the above to put category 3 and 4 together and assign up to $100.00 for possible expenses. The motion was seconded by G. T. Harvey and carried.

New Business — none

APPENDIX I

ENTOMOLOGICAL SOCIETY OF ONTARIO

Financial Statement for the year ending December 31, 1971

RECEIPTS		EXPENSES	
Dues Received	$ 1,784.28	Dues to Ottawa	$ 1,014.00
Sale of Reprints	2,864.90	Exch. & Disc. U.S. funds	37.38
Sale of Proceedings	113.68	Postage	563.20
Postage Prepayment	1,741.82	Printing	989.43
Bank Interest	354.62	Stationery	275.68
Bond Interest	18.00	Auditor	10.00
Ont. Gov't. Grant	300.00	Numerator	17.10
Cash (adv. to Ann. Meet.)	200.00	Refund of Dues	48.00
Receipt from Ann. Meet.	550.50	Deposit Error April 7/71	4.00
Premium U.S. Funds	3.42	Sec. Assist.	15.00
	$ 7,931.22	Honorarium	200.00
Bank Bal. Jan. 1/71	4,379.16	Cash Adv. Ann. Meeting	200.00
	$12,310.38	President's Prize	50.00
Bonds	2,400.00	Banquet (Talisman)	401.52
Inv. Cert.	785.69	Coffee (Can. Catering)	56.00
	$15,496.07	Bonds	2,000.00
			$ 5,881.31
		Bank Bal. Dec. 31/71	7,287.82
			$13,169.13
		Less ck o/s	858.75
			$12,310.38
		Bonds	2,400.00
		Inv. Cert.	785.69
			$15,496.07

Audited and found to
be correct.
January 25, 1972.

Signed: B. E. Saunders
H. T. Awrey

APPENDIX II

PRESIDENT'S PRIZE

Seven papers were presented by university students at the 108th Annual Meeting in the eleventh annual competition for the President's Prize (see names of students and titles of papers above). The judges were D. Oliver, G. Harvey and R. Byers. The prize was awarded to Harvey Lerer, University of Guelph.

Harvy Lerer was born in Poland in 1946, emigrating to Canada in 1948. He received his high school education in Toronto and entered the University of Guelph in 1965. In 1969 he received a B.Sc. degree in Honours Zoology and in 1971 a M.Sc. degree in Entomology. He is currently studying towards a Ph.D. degree in Insect Physiology under the direction of Dr. S. E. Dixon.

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I. REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

INSECTS OF THE SEASON 1972 RELATED TO FRUIT, VEGETABLES, FIELD CROPS AND ORNAMENTALS

H.W. Goble

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Abstract

In general, insects were at reasonable levels or well controlled in 1972 on fruit, vegetables, field crops and ornamental plants. Some injurious species at higher levels were apple maggot, mullein bug and hairy chinch bug.

* * * * * *

Fruit

Except for the apple maggot, the mullein bug and the tarnished plant bug, most fruit insects were well controlled. Apple maggot, *Rhagoletis pomonella* (Walsh), infestation was high in most areas of Ontario. A few of the best orchards showed an increase as a result of the very late emergence of flies. The mullein bug, *Campyloma verbasci* Meyer, caused widespread damage in apple orchards especially on Delicious with an almost complete loss of this variety in some orchards. The tarnished plant bug, *Lygus lineolaris* (Palisot and Beauvois), persisted in many orchards and caused damage on peaches, apples and strawberries. The obliquebanded leafroller, *Choristoneura rosaceana* (Harris), increased in numbers and caused up to 5% injury in some orchards. The tentiform leaf miner, *Lithocolletis blancardiella* Fab., caused less damage then in 1971 even though there was a heavy moth flight early in the season. The woolly apple aphid, *Eriosoma lanigerum* (Hausmann), increased in the last several years. The strawberry weevil, *Anthonomus signatus* Say, was active in a number of strawberry-growing areas.

Vegetables

Cutworm damage was, generally, not severe but several species caused some crop damage. A large cutworm (unidentified) was present in late summer and caused concern as it fed in the heart of mature celery resulting in the complete loss of infested heads. The cabbage maggot, *Hylemya brassicae* (Bouché) caused damage in May and June where control measures were incomplete. The total loss on cabbage, rutabagas and radish was not great. The cabbage looper, *Trichoplusia ni* Hübner), caused little injury. Damage from the European corn borer, *Ostrinia nubilalis* (Hübner), was not as serious as in 1971. An unusual record was corn borers feeding in the heads of late cabbage. The potato flea beetle, *Epitrix cucumeris* (Harris), was very plentiful in the Alliston area causing considerable foliage injury. The carrot rust fly, *Psila rosae* Fabricius, occurred in normal numbers. The carrot weevil,

Listronotus oregonensis (LeConte), increased slightly. Two cases of severe injury on celery were reported. The greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), has been a problem in a number of greenhouses. Some infestations originating in the greenhouse in the spring caused damage in fields and gardens.

Field Crops

There were localized attacks of the armyworm, *Pseudaletia unipuncta* (Haworth), in Dufferin County, the Niagara Peninsula and the Ottawa Valley. The alfalfa weevil, *Hypera postica* (Gyllenhal), is present throughout southern Ontario. The cold, wet spring delayed hatching and, generally, damage was light. The cereal leaf beetle, *Oulema melanopus* (Linnaeus), continued to increase. The damage to date has not been important with biological control being sufficient. The northern corn rootworm, *Diabrotica longicornis* (Say), caused damage in some fields in southwestern Ontario. This insect is of no importance from York County east.

Ornamental Plants

There are large numbers of insects and mites that are important on ornamental plants. Only a few of new or increased importance will be recorded. The hairy chinch bug, *Blissus leucopterus hirtus* Montandon, was not found on sod farms near Guelph this year but some lawns were severely damaged in widely separated areas such as Guelph, Simcoe, Sudbury and Sault Ste. Marie. A sod webworm, *Crambus* sp. caused damage to lawns at Bramalea. The European chafer, *Amphimallon majalis* (Razoumowsky), continued to spread west in the Niagara Peninsula causing considerable turf injury.

INSECTS AND OTHER ARTHROPODS OF IMPORTANCE DURING 1972 IN HOUSES, WAREHOUSES AND ON LIVESTOCK IN ONTARIO

W.C. Allan,

Department of Environmental Biology,
University of Guelph

Abstract

A resume of the occurrence in Ontario during 1972 of certain species of insects and other arthropods in houses, warehouses and livestock.

* * * * * *

Houses

Cluster flies, *Pollenia rudis* (F.) were very abundant in homes and other buildings during 1972. Reports of these flies in large numbers in living and working areas during the early spring and late fall were recorded. European earwigs, *Forficula auricularia* L., were plentiful during the summer months in gardens and

sometimes in homes. In some instances they caused severe damage to small vegetable plants and to the blooms of dahlias.

Many instances of fleas, *Ctenocephalides* spp. were reported as being annoying pests in homes. In all cases a cat or dog was involved. Millipedes, *Narcus* spp., were common in basements and around swimming pools. Large concentrations were frequently observed in driveways.

Saw-toothed grain beetles, *Oryzaephilus surinamensis* (L.), were found in kitchens and pantries.

Warehouses

Indian meal moth, *Plodia interpunctella (Hbn.)* was the insect most frequently reported in warehouses and grain storage areas. Larvae of this pest were found in a few instances in stored cereal products. Mites, *Acarus* spp., caused concern when found in certain pet foods. Confused flour beetle, *Tribolium confusum* duV., was reported from many warehouses in the province.

Livestock

Mosquitoes, *Aedes* spp., were very plentiful on pasturing cattle during 1972.

Horn flies, *Haematobia irritans* (L.) were fairly widespread and counts of four to five hundred per animal were not unusual. Populations of face flies, *Musca autumnalis* (DeG.), were very small during 1972, probably at its lowest level in many years.

Warbles, *Hypoderma* spp., appeared in beef and young cattle generally throughout the province but no instances of high populations were reported.

Biting flies, *Tabanus* spp., were observed on cattle in some areas. In stables and pens, house flies, *Musca domestica* L. were very plentiful and frequently became a serious problem.

PLANT PARASITIC NEMATODES OF ECONOMIC IMPORTANCE IN ONTARIO.

T.H.A. Olthof, C.F. Marks, J.W. Potter, and J.L. Townshend

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Abstract

Meloidogyne hapla Chitwood was responsible for damage to African violets in a greenhouse and to carrots and onions in muck soils. Soil population densities of *Heterodera avenae* Wollenweber declined under four years of continuous corn. *Paratylenchus tateae* Wu & Townshend was found in soil from corn, alfalfa and clover. *Trichodorus christiei* Allen and *Tylenchorhynchus parvus* Allen were associated with problems in field rhododendrons. *Longidorus elongatus* (de Man) Thorne & Swanger damaged field-grown flue-cured tobacco; pot tests showed sorghum was a good host but tobacco and rye were not. Tobacco yields did not

increase when Telone was placed below the conventional 6-inch depth in a Fox loamy sand. A Sudan grass cover crop promoted an increase in soil population densities of *Pratylenchus penetrans* (Cobb) in a peach orchard whereas creeping red fescue retarded its multiplication. Field microplot studies established relationships between population densities of *Heterodera schachtii* Schmidt and losses in five vegetable crops.

* * * * * *

There are several plant parasitic nematodes in Ontario soils that have an important economic impact on crop production. These are the root-lesion nematode, *Pratylenchus* Filipjev; the root-knot nematode, *Meloidogyne* Goeldi; the cyst nematode, *Heterodera* Schmidt; the dagger nematode, *Xiphinema* Cobb; the bulb and stem nematode, *Ditylenchus dipsaci* (Kuhn) Filipjev; and the pin nematode, *Paratylenchus* Micoletzky.

The northern root-knot nematode, *Meloidogyne hapla* Chitwood, caused a problem on African Violets *(Saintpaulia* sp.) at Pine Grove, Ontario. In a commercial greenhouse, imported stock-variety plants infested with root-knot nematodes were kept in pots on shelves above propagation benches and rooting beds. Infestation of the rooting beds and the potted plants on the propagation benches probably resulted from drainage of the overhead infested potted stock plants during watering. In a specimen pot, *M. hapla* larvae averaged 10,000 per pound of soil and 19,900 per ounce of root. The infested plants were chlorotic, unthrifty and wilted easily. Root growth was greatly reduced and the infested roots were heavily galled and necrotic.

M. hapla also continued to be a problem in some parts of the muck-vegetable growing areas at Port Colborne (Olthof *et al.* 1969) and Bradford, Ontario. Carrots in some fields of the Port Colborne marsh were severely galled by this nematode. In one case at the Bradford marsh, onions were severely stunted and galled at one side of a field which had been cropped to carrots the previous year. Soil fumigation had been carried out in November under cold conditions and the damaged part of the field had also received some protection from freezing by snow accumulation near an adjacent windbreak. The combination of frost protection by snow cover, unsatisfactory fumigation conditions and previous cropping to a good host of the root-knot nematode promoted damage to the onion crop.

The oat-cyst nematode, *Heterodera avenae* Wollenweber, continued to damage oats and corn in southwestern and eastern Ontario as in previous years (Olthof *et al.* 1971). However, weather conditions in 1972 favouring fungal root rots tended to obscure nematode-induced damage, especially with corn. Sampling of a field in continuous corn for the fourth consecutive year indicated that the oat-cyst nematode had almost disappeared, although other nematode genera continued to be present.

A new species of pin nematode, *Paratylenchus tateae* Wu & Townshend, was found in soil samples collected from corn, alfalfa and clover in Ontario (Wu & Townshend, 1973). Stubby-root nematodes, *Trichodorus christiei* Allen, and stunt nematodes, *Tylenchorhynchus parvus* Allen, were associated with a problem in field rhododendrons. It is believed that these nematodes may predispose this host to fungal problems, such as those caused by *Phytophthora* sp.

The first instance of the needle nematode, *Longidorus elongatus* (de Man) Thorne & Swanger, causing damage to flue-cured tobacco, or any economic crop in Ontario, was recorded in 1971 (Olthof *et al.,* 1971; Marks & Elliot, 1973). In greenhouse studies, sorghum, *Sorghum vulgare* Pers., the crop grown prior to the

damaged tobacco, was a good host for this nematode, whereas tobacco and rye, the rotation crops used by most tobacco growers, were poor or non-hosts for the nematode. Since most tobacco growers also apply a preplant nematicide to control the root-lesion nematode, *Pratylenchus penetrans* (Cobb), it is unlikely that *L. elongatus* will present any threat to tobacco production in Ontario.

An experiment with row application of Telone (1, 3-dichloropropene and related C_3 chlorinated hydrocarbons) for control of the root-lesion nematode, *P. penetrans*, in flue-cured tobacco on Fox loamy sand showed that at the recommended rate of 8 gallons per acre there was no advantage in placing the fumigant below the conventional 6-inch depth.

The most common soil management practice in Ontario peach orchards, clean cultivation until July 1 followed by a cover crop of weeds, resulted in large soil populations of the root-lesion nematode, *P. penetrans*. Sudan grass, *Sorghum vulgare* var. *sudanense* Hitch., a cover crop previously recommended for retarding population increases of *P. penetrans* in orchards, was found to be ineffective. In greenhouse and growthroom experiments, Sudan grass, buckwheat, *Fagopyrum esculentum* Moench and Italian rye grass, *Lolium multiflorum* Lam., were good hosts for *P. penetrans*. Field and pot tests indicated that creeping red fescue, *Festuca rubra* L., is an effective cover crop for retarding increases in numbers of *P. penetrans* in orchards. A soil management system, incorporating the use of herbicides to limit weed growth within the rows and maintaining a cover crop, such as creeping red fescue, between the rows might be of value to keep populations of the root-lesion nematode at low levels.

Five common commercial varieties of vegetables were grown in field microplots consisting of 8-inch clay tiles that contained 0, 300, 900, 2700 or 8100 sugar beet cyst larvae, *Heterodera schachtii* Schmidt/lb. of Vineland loam. In general, weights of marketable produce were inversely related to preplant nematode population densities. At the highest nematode density losses in marketable yields were: cabbage, 15%; cauliflower, 13%; beets, 28%; spinach, 50%; and rutabagas, 35%.

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NOTEWORTHY FOREST INSECTS IN ONTARIO IN 1972

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Abstract

A resumé is given of forest insects that, for a variety of reasons, were important or noteworthy in 1972. The species are dealt with under indigenous or introduced insects and further subdivided according to coniferous or broad-leaved trees upon which they feed.

* * * * * *

Indigenous Insects

Coniferous Trees

Once again, the spruce budworm, *Choristoneura fumiferana* (Clemens), dominated the forest insect scene. Numerous man-weeks were devoted to spruce budworm field operations including the determination of larval emergence time, larval-population sampling, evaluation of experimental and operational control efforts, trapping, mapping areas of defoliation, egg sampling, and tree mortality surveys. The area in which spruce and fir were moderately to severely defoliated (Fig. 1) increased over 1971 by approximately 50 per cent. In southern Ontario, the infestation extended south and west increasing in area from 4.5 to 5.8 million acres. Egg counts indicate that the outbreak will continue in 1973. In the Bonnechere Valley near Renfrew, tree mortality of both balsam and spruce is increasing. In northeastern Ontario, despite a late spring frost that in some stands killed most new balsam shoots and, directly or indirectly, a large proportion of the budworm larvae, the damaged area enlarged southward, increasing in size from 8.6 to 13.4 million acres. Egg counts indicate that there may be a slight spread to the south in 1973. Tree mortality is now becoming evident in the areas infested longest and is especially severe east of Lake Onaping, 50 miles north of Sudbury. In northwestern Ontario the situation is much brighter. Owing in part to abatement spraying carried out over 35,000 acres in this part of Ontario, the total area of moderate-to-severe defoliation decreased from 130,000 acres in 1971 to about 100,000 in 1972. Egg counts indicate that the potential extent of defoliation in 1973 has also lessened.

The only infestation of any consequence of the jack-pine budworm, *Choristoneura pinus pinus* Freeman, was located southwest of Byng Inlet where moderate-to-severe defoliation has recurred for three years. The complex of cedar leaf miners, *Argyresthia canadensis* (formerly *freyella*) Freeman, *A. aureoargentella* Brower, *A. thuiella* Packard and *Pulicalvaria thujaella* (Kraft) continued their depredation of eastern white cedar in southeastern Ontario south of a line from Arnprior to Toronto and there was considerable twig and branch mortality. Elsewhere in southern Ontario damage was less severe and sporadic. Populations of most native pine sawflies were at relatively low levels. The only exceptions were the red-headed pine sawfly, *Neodiprion lecontei* (Fitch), which was more abundant in the North Bay and Pembroke areas than it has been for a number of years, and the white pine sawfly, *N. pinetum* (Norton), which severely defoliated trees on islands near Parry Sound. High populations of a little-known white pine needle midge, *Cecidomyia*

pinifoliae (Felt), were reported in Presqu'ile Park and an obscure eriophyid mite, *Nalepella halourga* Keifer, caused damage to white spruce seedlings in a greenhouse at Petawawa.

Broad-leaved Trees

Two massive outbreaks of insect defoliators, one on aspen and the other on birch, were mapped (Sippell *et al.*, in press). The large aspen tortrix, *Choristoneura conflictana* Walker, was present in high numbers within an area of 50,000 square miles in northern Ontario. This is the 5th consecutive year of heavy damage to aspen stands west of Thunder Bay, an exceptional instance of infestation longevity. The birch skeletonizer, *Bucculatrix canadensisella* Chambers, caused moderate-to-severe damage to birch foliage in an area of 88,500 square miles, mostly in northern Ontario. Worthy of mention is the similarity in the areas affected by this pest in 1941 and 1972. Infestations of the forest tent caterpillar, *Malacosoma disstria* Hubner, in the vicinity of Fort Frances collapsed, but new infestations appeared to be developing between Dryden and Vermilion Bay in northwestern Ontario, west of the junction of highways 631 and 11 near Hornepayne and in the New Liskeard-Earlton area of northeastern Ontario. The oak leaf tier, *Croesia semipurpurana* Kearfott, was more prevalent and widespread than usual, with severe defoliation of red oak occurring in pockets throughout southern Ontario, near Sault Ste. Marie and Blind River and on Manitoulin Island in northern Ontario. Infestations of three *Anisota* species occurred as follows: the pink-striped oakworm, *A. virginiensis* Drury, caused severe defoliation in Driftwood Park on the Ottawa River; infestations of the orange-striped oakworm, *A. finlaysoni* Riotte, persisted in the Kingston-Belleville area, with new infestations developing in white oak surrounding Hamilton; and heavy infestations of the green-striped mapleworm, *A. rubicunda* Fabricius, persisted on red maple near North Bay and Pembroke but declined on Manitoulin Island. Black cherry northeast of Bowmanville again suffered defoliation by the looper, *Hydria prunivorata* Ferguson. Unusually heavy feeding by rose chafer adults, *Macrodactylus subspinosus* Fabricius, on many deciduous trees was common in southeastern Ontario, and elm in the Sharbot Lake area was heavily damaged by the elm lace bug, *Corythucha ulmi* Osborn and Drake. The little-known willow blotch miner, *Micurapteryx* sp., was prevalent on willow between Hearst and Nakina, and the cherry shoot borer, *Argyresthia oreasella* Clemens, caused heavy shoot mortality on hawthorn, an unusual host in widely scattered areas of southwestern Ontario. Heavy leaf damage to basswood between Bobcaygeon and Burleigh Falls was caused by thrips tentatively identified as *Sericothrips tiliae* Hood.

Introduced Insects

Coniferous Hosts

One of the main methods by which the European pine sawfly, *Neodiprion sertifer* (Geoffroy), is spread northward was redocumented when spring planted ball stock of Mugho and Austrian pine was found infested near Bracebridge and Dorset. After 6 years of very low population levels of this pest in plantations on Manitoulin Island where a polyhedral virus of *sertifer* had been disseminated, a fivefold increase was reported in the average number of colonies per tree, the highest being 1.5. Two other introduced pine sawflies extended their northward range. The introduced pine sawfly, *Diprion similis* (Hartig), was found on white pine at a number of points south of Lake Muskoka, probably the result of natural spread, and the nursery pine sawfly, *Diprion frutetorum* Fabricius, appeared to be extending its northern distribution on a 300-mile front from Cockburn Island in the North Channel of Lake Huron through Powassan on Highway 11 to Pembroke on the Ottawa River.

Broad-leaved Trees

High population levels of the birch leaf miner, *Fenusa pusilla* (Lepeletier), were common in the recently invaded areas of northwestern Ontario, but no extension in its northern range was noted. However, the birch leaf miner, *Messa nana* Klug, is rapidly spreading westward in southwestern Ontario and now occurs near Simcoe and Goderich. The European snout weevil, *Phyllobius oblongus* Linnaeus, continued to cause severe damage to deciduous trees and shrubs near Mindemoya on Manitoulin Island. Collections of the satin moth, *Stilpnotia salicis* Linnaeus, on scattered silver poplar trees near Cornwall and Lancaster constitute one of the first Ontario survey records. Plant Protection Division, Canada Department of Agriculture, the organization responsible for surveys of and control operations against the gypsy moth, *Porthetria dispar* Linnaeus, reports that the infested area near Kingston has been reduced to 4,000 acres, one third of that infested in 1971, but a small increase in area was noted near Cornwall. Sex traps baited with Disparlure and placed in most provincial parks across Ontario caught an adult male moth at Ignace in northwestern Ontario.

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FOREST DISTRICTS
1. KEMPTVILLE
2. TWEED
3. LINDSAY
4. LAKE SIMCOE
5. LAKE HURON
6. LAKE ERIE
7. PEMBROKE
8. PARRY SOUND
9. SUDBURY
10. NORTH BAY
11. SAULT STE. MARIE
12. SWASTIKA
13. CHAPLEAU
14. WHITE RIVER
15. COCHRANE
16. KAPUSKASING
17. GERALDTON
18. THUNDER BAY
19. SIOUX LOOKOUT
20. FORT FRANCES
21. KENORA
KENORA
THUNDER BAY
SAULT STE MARIE
OTTAWA
TORONTO
LAKE HURON
LAKE ONTARIO
1972
Areas of moderate-to-severe infestations of
SPRUCE BUDWORM
(Damage in some parts of northeastern areas resulted from spruce budworm combined with frost)
SCALE IN MILES
0 40 80 120 160 200

II. SUBMITTED PAPERS

PROCEEDINGS OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO

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BEHAVIOUR AND PERSISTENCE OF BIOLOGICAL ACTIVITY OF HCS-3260 (AG-CHLORDANE) IN SOIL UNDER LABORATORY CONDITIONS[1]

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Abstract

A laboratory study was conducted to determine the behaviour and persistence of HCS-3260 (AG-chlordane) in soil relative to technical chlordane, heptachlor, and heptachlor epoxide. GLC analysis indicated that technical chlordane contained 8.5% heptachlor, 8.6% α -chlordane, 10.5% γ -chlordane, and 2.7% nonachlor. HCS-3260 contained 1, 68, 29.4, and 0.6% of the 4 compounds respectively. As a contact insecticide HCS-3260 showed a spectrum of activity and toxicity similar to technical chlordane and both compounds were ca. 1/10 as toxic as heptachlor and its epoxide. The activity of all insecticides was influenced by soil and climatic factors. The behaviour of technical chlordane in soil was similar to that of heptachlor and both were moderately volatile and persistent. By contrast the behaviour of HCS-3260 in soil paralleled that of h. epoxide. Both were of limited volatility and highly persistent in soil.

* * * * * *

The uses of several organochlorine insecticides have been phased out in Ontario because of undesirable environmental side effects. As a result technical chlordane is being utilized much more extensively than in the past for control of soil insects such as white grubs and the northern corn rootworm. Technical chlordane consists of a mixture of a number of compounds, the main insecticidal components being

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1) Contribution No. 553, Research Institute, Canada Department of Agriculture, London, Ontario.

2) The technical assistance of S. Turnbull, B. Shoemaker, and W.W. Sans is acknowledged. Insecticide samples were provided by the Velsicol Corporation.

heptachlor, α - and γ -chlordane, and nonachlor. It is less active than the other cyclodiene insecticides and is used at higher rates of application. Harris (5) showed that much of the insecticidal activity of technical chlordane was due to its heptachlor content of ca. 8 1/2%, although heptachlor is one of the insecticides whose uses have been most severely restricted in Ontario. Alpha- and γ -chlordane, while only 1/10 as toxic as heptachlor in soil (5), are still relatively effective soil insecticides and thus offer a possible alternative for soil insect control. This report summarizes the results of a laboratory study on the behaviour and persistence of biological activity of HCS-3260 (AG-chlordane) in soil.

Methods and Materials

Test insects included 24-48 hour old 1st-stage crickets, *Gryllus pennsylvanicus* (Burmeister), 24-48 hour old adult picture-winged flies, *Chaetopsis debilis* (Loew), and 3rd-stage black cutworm *Agrotis ipsilon* (Hufnagel). Rearing procedures have been described (7, 8, 9). Unless otherwise specified tests were done with crickets.

All insecticides used were reference grade materials. The activity of HCS-3260 was measured against technical chlordane, heptachlor, and heptachlor epoxide. Procedures for assessment of direct contact toxicity, activity in soil, and persistence of biological activity have also been given in detail elsewhere (3, 6), and thus will be described only briefly.

The direct contact toxicity of HCS-3260 relative to the other insecticides was assessed using a Potter spray tower. Four insecticide concentrations were used: 0.001, 0.01, 0.1, and 1% solution (19:1 acetone:olive soil solvent mixture). Duplicate groups of 10 insects were tested at each concentration. A solvent control was included with each test. Tests were conducted on all 3 species of insects. Following treatment, crickets and flies were placed in observation containers and provided with food and water. Cutworms were placed in similar containers containing 50 ml moist Plainfield sand. Food was provided. Mortality counts were made after 18 hour with crickets and flies, and 42 hour for cutworms.

Assessments of the behaviour of HCS-3260 in soil relative to the other insecticides were made by incorporating the insecticide, dissolved in distilled chromatographed n-pentane, into the soil and evaporating the solvent. In initial studies to determine the relative effectiveness of the 4 insecticides in moist Plainfield sand (5% water) log dosage-probit lines were determined. Tests were also conducted to determine the effect of soil and climatic factors on insecticide toxicity. To determine the influence of soil type, insecticide activity was compared in 2 soils representing the extremes in agricultural soils in Ontario, i.e. a Plainfield sand (5% water, 0.5% organic matter) and a muck soil (117% water, 65% organic matter). The influence of soil moisture was determined using the Plainfield sand at 0.5% (air-dry) and 5% (field moist) water, while soil temperature effects were determined by running tests at 15 and 33°C. These temperatures were selected since they represent the maximum and minimum soil temperatures which might be encountered in Ontario from April to June when soil insecticides are applied. In all these tests, 7 insecticide concentrations were used, 0.1, 0.5, 1, 5, 10, 50, and 100 ppm (calculated on the basis of the oven-dry wt of the soil). Duplicate groups of 10 insects were tested at each concentration and a solvent control was included with each test. Following treatment of the soil and evaporation of the solvent, aliquots were weighed into containers, moisture and food provided, crickets introduced, and containers covered. Mortality counts were made after 18 hr.

Volatility of the 4 insecticides was assessed by measuring fumigant effect on crickets placed on a gauze screen suspended 0.5 cm above the surface of treated

Plainfield sand. The insecticides were applied to the soil at concentrations of 2 and 4 x the LD_{50} obtained when the insects were placed directly on the soil. Mortality counts were made after 18 hr.

Persistence of biological activity of the 4 insecticides was determined in Plainfield sand. Insecticide concentrations used were 4 x the LD_{50}, i.e. HCS-3260 5.14, technical chlordane 3, heptachlor epoxide 1.04, and heptachlor 0.8 ppm. Soils were brought up to field moisture capacity each week and samples removed and bioassayed at intervals up to 48 wks using crickets as the test insects.

All tests were conducted using environmental chambers programmed to provide $27 \pm 1°C$, $65 \pm 5\%$ RH, and 24 hour photoperiod unless otherwise specified. Corrections for natural mortality (never > 10%) were made (1). Log dosage probit lines were computed (2).

Results and Discussion

As noted above, it has been shown that much of the insecticidal activity of technical chlordane is due to its heptachlor content (5). GLC analysis of reference grade technical chlordane used in these tests indicated that the sample contained 8.5% heptachlor, 8.6 α -chlordane, 10.5% γ -chlordane, and 2.7% nonachlor. The sample of HCS-3260 contained 1% heptachlor, 68% α -chlordane, 29.4% γ -chlordane, and 0.6% nonachlor. On the basis of earlier data (5) on the toxicity of the 4 compounds, approximately 90% of the insecticidal activity of the HCS-3260 would be due to the α - and γ -chlordane content, while 8-9% its insecticidal activity would result from the 1% heptachlor in the sample. As a direct contact insecticide the toxicity of HCS-3260 was similar to that of technical chlordane (Table I) against crickets, flies, and cutworms. Both compounds were ca. 1/10 as toxic to the insects as heptachlor and they were also less toxic than heptachlor epoxide.

TABLE I. Direct contact toxicity of HCS-3260, technical chlordane, heptachlor and heptachlor epoxide to 3 species of insects.

Insecticide	Avg. corr. % mortality at indicated % solution			
	0.001	0.01	0.1	1.0
		Crickets		
H. epoxide	0	70	100	100
Heptachlor	0	10	100	100
HCS-3260	0	0	100	100
T. chlordane	0	0	100	100
		Flies		
H. epoxide	0	100	100	100
Heptachlor	0	100	100	100
HCS-3260	0	0	100	100
T. chlordane	0	0	100	100
		Cutworms		
Heptachlor	0	0	80	100
H. epoxide	0	0	15	100
HCS-3260	0	0	0	73
T. chlordane	0	0	0	60

The information obtained on the activity of the insecticides in soils has been summarized as briefly as possible. Rather than including mortality data obtained at all 7 insecticide concentrations tested, only the lowest concentrations of insecticide which caused corrected percentage mortalities of 10% or more have been tabulated.

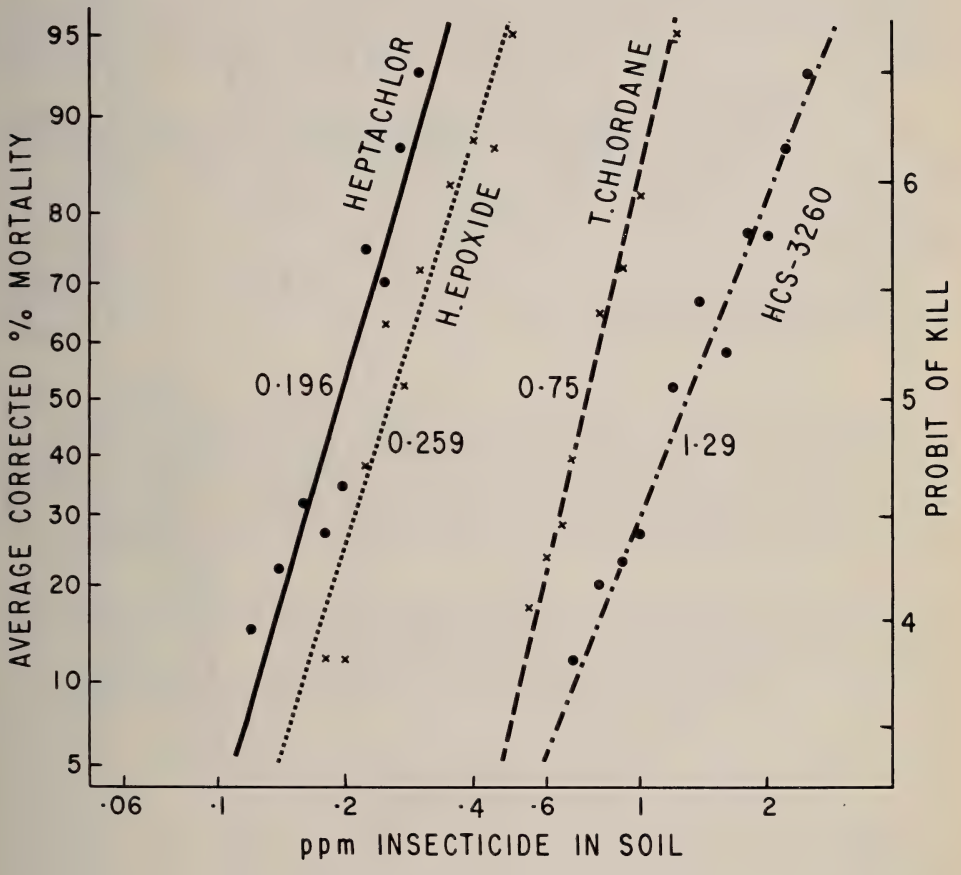

FIGURE 1. Dosage-mortality curves obtained in assays of the toxicity of HCS-3260, technical chlordane, heptachlor and heptachlor epoxide in moist Plainfield sand using 1st stage crickets as test insects.

In moist mineral soil, the order of toxicity was heptachlor > heptachlor epoxide > technical chlordane > HCS-3260 (Table II). In the more detailed studies the dosage-mortality curves (Fig. 1) indicated that in Plainfield sand, heptachlor epoxide and heptachlor were 5-6 x as toxic as HCS-3260 to crickets, while technical chlordane was 1.7 x as toxic.

TABLE II. Influence of soil type and moisture on the toxicity of HCS-3260, technical chlordane, heptachlor and heptachlor epoxide to 1st stage crickets.

Insecticide	Lowest insecticide conc. (ppm) showing equivalent toxicity		Ratio:
	Soil Type[1]		
	Sand (5% water)	Muck (117% water)	Muck/Sand
HCS-3260	5	50	x 10
H. epoxide	0.5	5	x 10
Heptachlor	.1	5	x 50
T. chlordane	1	50	x 50
	Soil Moisture[1]		
	Sand (5% water)	Sand (0.5% water)	0.5/5
HCS-3260	5	5	x 1
H. epoxide	0.5	1	x 2
Heptachlor	.1	0.5	x 5
T. chlordane	1	5	x 5

1) All tests conducted at 27 ±1°C.

Insecticidal activity is moderated by soil and climatic factors (4). Tests on the effect of soil type on activity (Table II) indicated that all insecticides were less active in the muck as compared to the mineral soil. The activity of HCS-3260 was similar to that of heptachlor epoxide in that it was 1/10 as toxic in the organic soil. Heptachlor and technical chlordane was 1/50 as toxic. Although of less importance,

TABLE III. Influence of soil temperature on the toxicity of HCS-3260, technical chlordane, heptachlor, and heptachlor epoxide to 1st stage cricket nymphs.

Insecticide	Lowest insecticide conc. (ppm) showing equivalent toxicity		Ratio: 15/33
	15°C	33°C	
	Plainfield sand - 5% water		
H. epoxide	0.5	0.1	x 5
Heptachlor	.5	.1	x 5
HCS-3260	5	1	x 5
T. chlordane	5	1	x 5
	Plainfield sand - 0.5 water		
Heptachlor	5	.5	x 10
H. epoxide	5	.5	x 10
T. chlordane	10	1	x 10
HCS-3260	50	5	x 10
	Muck - 117% water		
T. chlordane	50	10	x 5
HCS-3260	50	10	x 5
Heptachlor	50	5	x 10
H. epoxide	50	5	x 10

soil moisture also influenced insecticide activity (Table II). Its effect on the toxicity of HCS-3260 was slight. At 5 ppm HCS-3260 caused 100% mortality in sand containing 5% water, while at 0.5% mortality was 48%. Soil moisture also was of minor importance with heptachlor epoxide, but had a more marked effect on the toxicity of heptachlor and technical chlordane. In mineral soil, temperature influenced the toxicity of all 4 insecticides to a similar extent, in that all were ca. 5 x as toxic at 33 as at 15°C (Table III). In air-dry sand the temperature effect was more pronounced, with the insecticides all being 10 x as toxic at 33 as at 15°C. In moist muck soil, technical chlordane and HCS-3260 were 5 x as toxic at 33 as at 15°C, while heptachlor and its epoxide were 10 x as toxic.

TABLE IV. Fumigant toxicity of HCS-3260, technical chlordane, heptachlor, and heptachlor epoxide in moist (5% water) Plainfield sand to 1st-stage crickets.

Insecticide	ppm (2 x LD_{50}) in soil	Avg. corr. % mortality	ppm (4 x LD_{50}) in soil	Avg. corr. % mortality
Heptachlor	0.4	75	0.8	95
H. epoxide	0.5	0	1.0	20
T. chlordane	1.5	75	3.0	100
HCS-3260	2.6	0	5.2	7

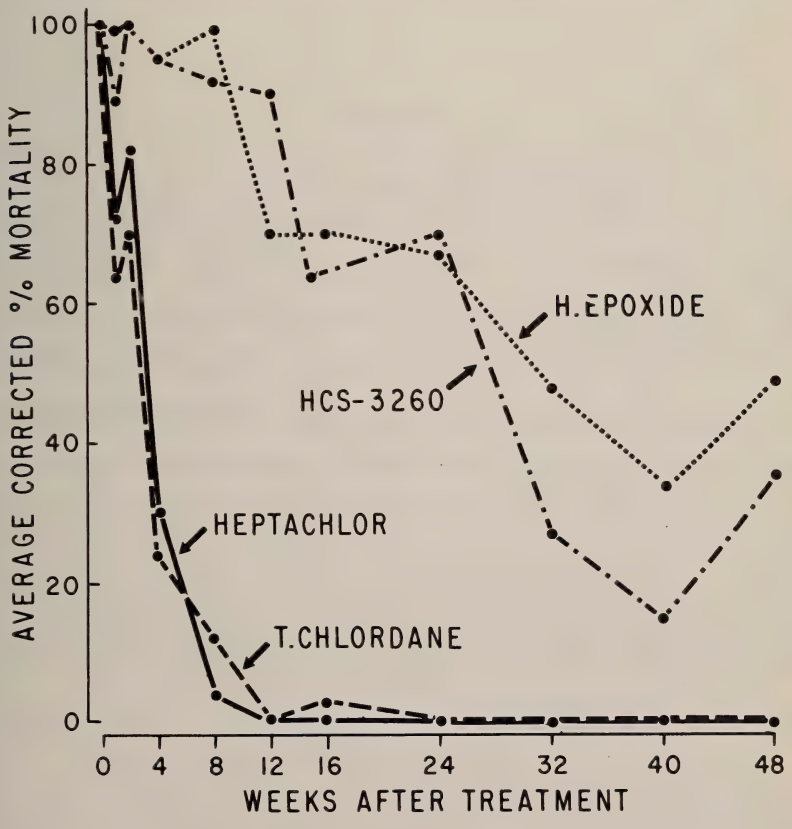

FIGURE 2. Relative persistence of biological activity of HCS-3260, technical chlordane, heptachlor, and heptachlor epoxide in Plainfield sand (Test insects= crickets; Test conditions= 27 ± 1°C, 65 ±5% RH, 24 hour photoperiod).

The fumigant toxicity tests indicated that all 4 insecticides were sufficiently volatile to cause fumigant toxicity to crickets placed 0.5 cm above the surface of the treated soil. At a concentration of 2 x the LD_{50} for treated soil heptachlor caused 75% mortality. Since the activity of technical chlordane is due largely to its heptachlor content, similar results were obtained in the fumigant toxicity tests with this compound. H. epoxide and HCS-3260 were less volatile with no mortality occurring at 2 x the LD_{50} in soil, and low mortality at 4 x the LD_{50}.

In mineral soil, the persistence of biological activity of heptachlor and technical chlordane was similar (Fig. 2). Both insecticides were moderately persistent, with biological activity disappearing in 12-16 weeks. By contrast, HCS-3260 and heptachlor epoxide were highly persistent, with biological activity persisting over the entire 48 week test period.

From the results of this study it is apparent that, as a contact insecticide, HCS-3260 will show toxicity and a spectrum of activity similar to that of technical chlordane. As a soil insecticide it appears to be slightly less active than technical chlordane, but still can be classed as effective. It is less volatile in soil than technical chlordane. The behaviour of HCS-3260 in soil in relation to soil and climatic factors and persistence of biological activity closely parallels that of heptachlor epoxide. By contrast, the activity and persistence of technical chlordane is similar to that of heptachlor.

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A STUDY OF INFESTATION BY THE EUROPEAN CORN BORER, *OSTRINIA NUBILALIS* (HUBNER) (LEPIDOPTERA: PYRALIDAE), IN SOUTHWESTERN ONTARIO, 1946 to 1964

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Abstract

A 19-year study of European corn borer, *Ostrinia nubilalis* (Hübner), infestation in grain corn in south-western Ontario is reported. Field surveys, in late summer, showed that plant damage and high larval populations are cyclical and dependent on favorable and highly critical weather factors. Droughts and/or low night temperatures during the main growing season deter larval establishment. Years suitable for good crop growth favour infestation. Areas of highest infestation were located in the extreme southwestern portion of the province where two generations of this insect occur.

* * * * * * *

Introduction

Haeussler and Leiby (1952) point out that insect population surveys may be conducted in a number of ways and for a variety of reasons, but they are the foundation of intelligent insect control programs. Cooperative surveys of insect populations, particularly of injurious forms, have been receiving more attention in recent years. In the United States, survey reports are periodically issued in the Cooperative Economic Insect Report. In Canada, the results of insect surveys are briefly reported in the Canadian Insect Pest Review for agricultural pests, and in the annual report of the Canadian Forestry Service for forest insects. The present paper reports the trend of infestation by the European corn borer, *Ostrinia nubilalis*, (Hu bner) in southwestern Ontario from 1946 to 1964, and briefly reviews factors affecting infestation from year to year in the various counties included in the survey.

Status reports on the European corn borer have been issued by the U.S. Department of Agriculture since 1931 (Beck, 1952). According to a recent (1972) issue of the Cooperative Economic Insect Report, there are now 14 participatory states. In Ontario, an annual corn borer survey was conducted each fall from 1926 to 1945 by the Department of Entomology and Zoology at the Ontario Agricultural College, Guelph. The primary purpose of this survey was to check on the effectiveness of the Corn Borer Act of 1927 (Caesar, 1931). Reports were issued periodically. One hundred plants were examined in each field to determine the percentage of infested plants and 30 fields were visited per county. It was a visual observation of each plant from the tassel to soil level. No plant was cut to determine the number of borers per plant (Thompson and Goble, 1946).

This type of survey served very well for the intended purpose; it did not, however, give an accurate account of the status of the corn borer during that particular period. A more detailed and systematic study was considered to be

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necessary. This was initiated by the writer, with assistance from Professor H.W. Goble, in 1946. The aim of this revised survey was to examine fewer fields more intensely, and to dissect completely a given number of plants in each field surveyed. Since this type of survey was similar to that used in the American Corn Belt, it was felt that the results obtained would be comparable with those found by U.S. entomologists. The methods used have been described by Beck (1952) and, with some modifications, these methods had been adopted in southwestern Ontario in 1946, after consultation with the American workers.

Description of Study Area

The area under study comprised the counties of Essex, Kent, Elgin, Lambton, and Middlesex, which represent the peninsular portion of southwestern Ontario. This area, according to Putnam and Chapman (1938), resolves itself into three distinct climatic regions. These are: (1) Leamington, (2) Kent and Essex, and (3) Lake Erie counties.

The Leamington region extends from the eastern base of Point Pelee to the southern limit of the city of Windsor. It follows the shoreline of Lake Erie and forms a narrow band about five miles wide. This is the earliest and warmest part of the province; the annual precipitation is the lowest in Ontario and droughts are frequent. Kent and Essex constitute an area of low relief, lying between lakes St. Clair and Erie. The prevailing soil type is heavy clay, interspersed in Kent with pockets of lighter soils. This area has been the centre of seed corn growing in Canada for many years, and many other cash crops are also grown here. The Lake Erie counties are bounded by Lake Erie on the south, Lake Huron on the west, and Lake Ontario on the east. As one advances eastward, glacial moraines become more evident and the land is hillier. Precipitation is greater than in either of the other regions and soil types are more varied. Cash crops are less evident.

During the period of this study, between 80% and 90% of the grain corn grown in Ontario was located in the area just described. Today (1973) this area is still the most important grain corn area of Canada, but other parts of the province now grow large acreages. The corn borer remains the most important insect pest of corn in Ontario.

Methods

A given number of fields was chosen at random in each county, after location points had been pin-pricked on a standard county highway map. The field nearest to a marked spot was sampled. The number of fields surveyed in each county was based on the acreage of shelled corn grown. Thus, in Kent and Essex, which grow nearly 70% of the shelled corn in Ontario, more unit samples were taken than in the other counties included in the survey.

One hundred plants were examined per field, the first plant being at least 50 paces from the edge of the field. The chosen plants were not examined consecutively; instead, the field was subdivided according to the number of operators. If four operators were engaged in the survey, the field was quartered and 25 plants were examined in each quarter. Thirty-three plants were examined in each third if three operators were present, with an extra plant being taken in one-third of the field. Ten infested plants were dissected per field. These were taken at random from the plants previously examined for stalk infestation.

All the plants were dissected if less than 10% damage was found in the field under examination. For example, if a field were surveyed and it was found that only nine plants were infested out of 100 examined, then all the infested plants would be

TABLE I. Infestation survey of *Ostrinia nubilalis;* percentage plant damage in grain corn, southwestern Ontario, 1946-1964

Location	Year																			
	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	Average
Essex	25	43	41	88	64	59	20	47	12	75	51	27	17	26	22	17	23	8	8	35
Kent	29	43	38	72	39	38	16	18	8	40	35	27	17	20	13	6	6	2	2	25
Elgin	24	47	36	42	32	40	29	26	3	8	32	27	37	24	13	15	10	5	6	24
Lambton	19	34	27	36	27	26	10	13	2	12	28	23	38	28	23	13	7	9	9	23
Middlesex	10	30	20	21	13	27	10	19	5	8	30	23	36	43	37	23	12	19	13	21
District	24	40	32	54	38	36	19	27	8	41	39	26	21	25	21	14	13	7	7	26

TABLE II. Larval population of *Ostrinia nubilalis* per 100 plants in grain corn, southwestern Ontario, 1946-1964

Location	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	Average
Essex	35	138	120	549	179	167	17	109	8	384	184	46	23	50	28	22	40	3	3	111
Kent	40	87	77	310	70	71	14	32	5	148	63	27	18	28	7	5	8	1	1	54
Elgin	12	115	81	109	70	68	36	39	3	12	53	39	63	62	8	26	9	1	5	43
Lambton	17	53	50	48	40	32	8	11	2	24	59	27	82	40	37	78	12	12	5	34
Middlesex	9	42	30	26	11	24	13	11	2	6	48	27	86	141	19	18	4	4	4	29
District	23	87	72	292	104	83	19	48	5	173	101	33	31	53	20	25	15	3	4	63

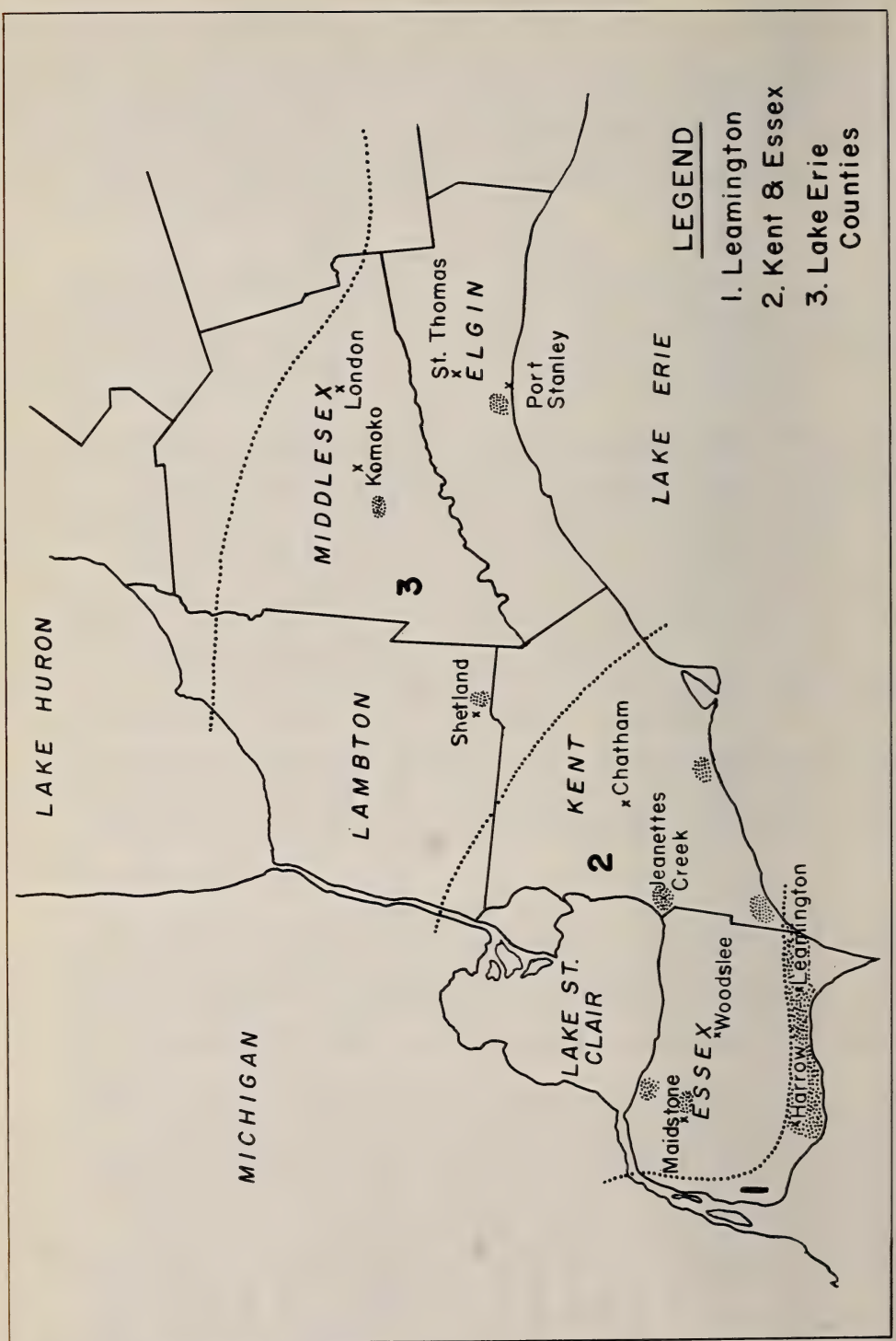

FIGURE 1. Climatic regions of southwestern Ontario and areas of heavy infestation by the European corn borer.

dissected and the borer population for the field thus ascertained. The population per field was calculated as follows: assuming the stalk infestation to be 90%, and the number of borers per 10 dissected stalks to be 25, then the actual borer population would be $\frac{90x25}{10}$ or 225 borers per 100 plants.

All parts of the plants were carefully dissected, including the ears if they showed signs of infestation after the husk had been removed. A record of the larval instars was kept for each field, beginning in 1949. Before that year, a note had been made of the percentage of multivoltine borers per field, but no count was kept of the various instars.

Results and Discussion

The number of fields surveyed varied slightly each year. As pointed out previously, more samples were taken in Kent and Essex than in the other counties. The average number of fields examined each year were: Kent, 28; Essex, 28; Elgin, 15; Middlesex, 12; and Lambton, 8. The average infestation for each county, from 1946 to 1964, is given in Table I. Each county will be discussed separately.

In general, the corn borer infestation is highest in the main corn-producing areas of Essex and Kent. This is exemplified better in Table II, which shows the number of borers found per 100 plants by actual plant dissection.

More borers were found in Essex than in any other of the counties that constituted the survey area. A glance at the map (Figure 1) will show a number of cross-hatched areas; one in each of Elgin, Lambton, and Middlesex, and three in both Essex and Kent. Such marks designate areas where the corn borer is always plentiful in any but a year of low infestation.

Essex. As noted above, Essex is divided into two climatic zones—(a) Leamington, (b) Essex and Kent. Corn borer infestation is always more plentiful in the Leamington zone. By way of example, two years, 1949 a year of severe infestation, and 1952 a year of light infestation, may be compared. Table III shows the difference in the two regions.

There are two other small areas in Essex County where corn borer infestation is generally severe, but not to the same extent as in the Leamington zone. These areas are located near Maidstone and south of Tecumseh. In 1949, the highest count in the history of the survey was made near Maidstone, where 1,350 borers per 100 plants were recorded. In 1952, in the same general region of Maidstone, only 11 borers were found per 100 plants.

TABLE III. Percentage stalk infestation and borers per 100 plants in Leamington zone and the rest of Essex County

Location	Year	% stalk infestation	Borers per 100 plants
Leamington	1949	99.0	700
	1952	32.0	45
Essex (remainder)	1949	83.0	500
	1952	15.5	7

Kent. The greater part of the county of Kent is included in the Essex and Kent climatic zone. Somewhat less than a quarter of the eastern part of the county is included in the Lake Erie counties region. This eastern section is not as productive as the rest of Kent, being composed, for the most part, of sandy or gravelly-loam soils. Infestation by the corn borer is usually low in the eastern part of the county. In general, the severity of infestation by the corn borer increases in Kent County as one goes westward. With the exception of 1946, the corn borer population has always been higher in Essex than in Kent, at least during the period under discussion. Areas of high infestation are found near Cedar Springs, Jeannette's Creek, and east of Wheatley.

Elgin. There are a number of very good corn-growing areas in Elgin, but they are scattered throughout the county. Some excellent fields are found in the river flats, north of Campbellton. Other good locations are in the general neighbourhood of Aylmer, and east and west of Union. It was near Union, on the west bank of Kettle Creek, that the corn borer became an important economic pest of corn in Canada in 1920. Heavily infested fields may still be found in some years in this small area. Infestation in Elgin is more even than in Essex and Kent; there are neither steep peaks nor deep valleys in the records, except in 1954 and 1963, when populations were low.

Middlesex and Lambton. Corn growing is confined mainly to the southern half of Middlesex, and only the three southern townships in Lambton were included in the annual survey. Infestation is always much lower in these two counties than in the rest of the survey area. There are two small areas where the borer population is usually higher than in other parts of the counties. One is located near Shetland, in Lambton; the other area is in the river flats, south of Komoka, in Middlesex. Neither location is comparable with the areas of high infestation found in the other three counties.

Weather and Corn Borer Infestation

A great deal has been written about the effect of weather on the development of, and subsequent infestation by, the corn borer. References to this subject may be found in the review by Brindley and Dicke (1963). At Chatham, Mutchmor and Beckel (1958), Barlow and Mutchmor (1963), and Barlow *et al.* (1963), have advanced various hypotheses relating to rainfall and borer infestations. Stirrett (1938) had a more practical approach and many of his methods foreshadowed ecological studies in vogue today. In spite of all this, however, it is difficult to say which weather factors exert the greatest influence on corn borer infestation. At this point, a statement by Mills (1952) seems apropos to the discussion. He states: "Weather effects on insects often act over a short period, and the critical period may be missed in the field and completely hidden in the published weather data." Consultation, by the writer, of weather records issued by the Meteorological Branch, Canada Department of Transportation and Communications, has shed little light on the critical period suggested by Mills, but some interesting facts, related to the effect of weather on corn borer infestation, have confirmed earlier studies by Barber (1926) and Stirrett (1938).

Two graphs, Figures 2 and 3, show the average plant infestation and the borers per 100 plants, respectively, for the survey area during the period 1946 to 1964. More detailed information for each county, as mentioned earlier, is given in Tables I and II. Examination of the graphs shows that there were two years, 1949 and 1955, when borer infestation was very high and two years, 1954 and 1963, when the infestation was very low; in fact, almost non-existent.

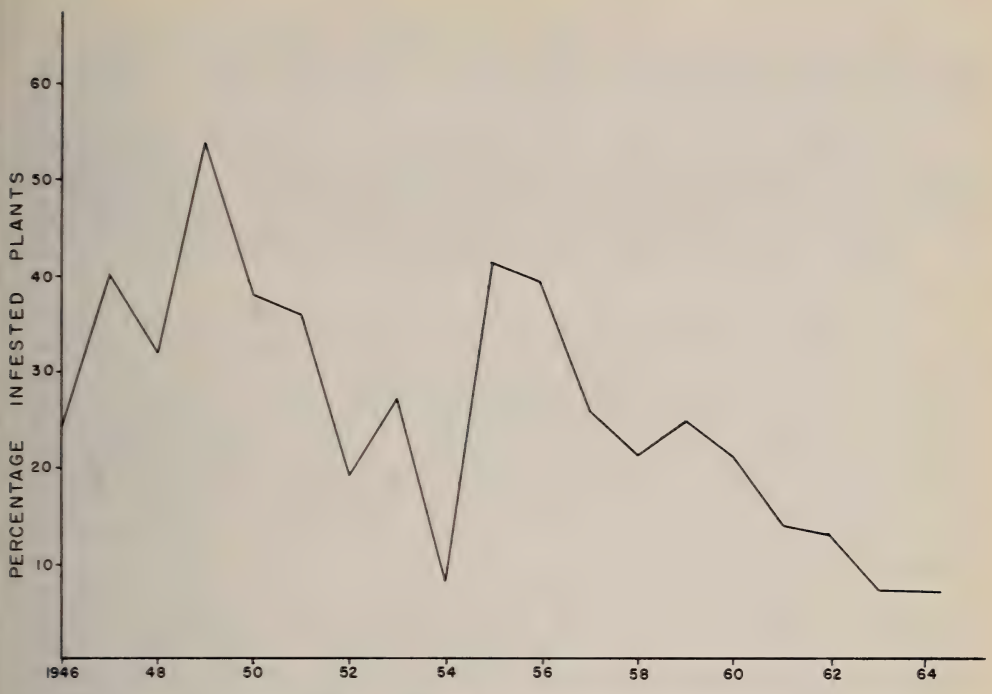

FIGURE 2. *Ostrinia nubilalis* stalk infestation in southwestern Ontario surveys. 1946-1964.

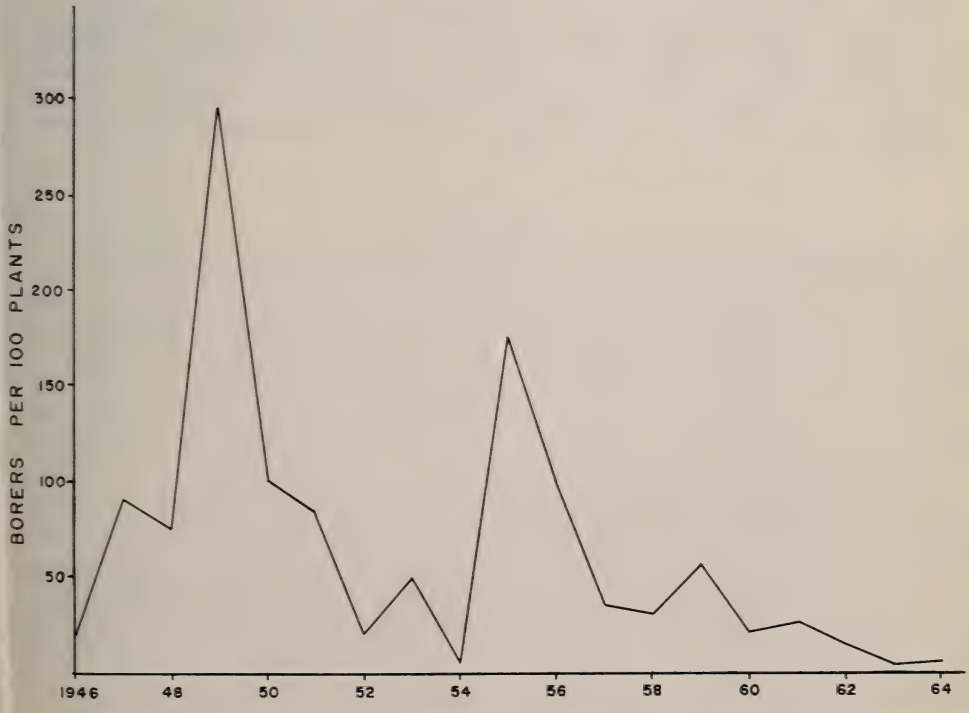

FIGURE 3. *Ostrinia nubilalis* populations in southwestern Ontario surveys. 1946-1964.

Reference to weather data for these four years is of great interest. Tables IV and V show the precipitation and the temperatures for the summer months, as recorded at Chatham, Ontario.

Both 1949 and 1955 were considered good corn years by the growers, particularly in Kent and Essex, where high night temperatures and adequate rainfall prevailed. On the other hand, 1954 was considered a drought year, when only 50% of the normal amount of rainfall was recorded, while 1963 was regarded as a poor crop year, generally, partly because of the low rainfall but also because of very low temperatures in August.

In his studies on moth flight in the field, Stirrett (1938) found that activity ceases when night temperatures reach 57°F. In the present study it was found that 57°F occurred more nights in 1954 and 1963 than in either 1949 or 1955. The number of times this happened during the three summer months is as follows: 1949 (13), 1955 (12), 1954 (35), and 1963 (36). In both 1954 and 1963, night temperatures frequently fell below 50°F; this was more evident in 1963. Nearly 50 years ago, Barber (1926) attributed declines in population to such unfavorable weather factors as low night temperatures, rains or lack of rains, and heavy winds during the early establishment period. He felt that subnormal night temperatures played an important part in limiting infestation.

Two other years, 1961 and 1962, had relatively low infestations (Table I), particularly in Kent County. In 1961, temperatures were very erratic in June; on four days a maximum of 90°F was reached, but maxima were under 69°F on seven occasions. Minimum temperatures below 57°F were recorded 17 times in this month, and below 50°F on 10 occasions. Consequently, June was considered a cold month, on the average, and unfavorable for the establishment of first-generation larvae. The summer of 1962 was very cool. At Windsor, daily temperatures averaged 3.4°F below normal in July of this year and 1.5°F below normal in August. Temperatures at Chatham were similarly low. Record new low minimum and maximum temperatures were recorded at the Windsor Airport (Monthly Meteorological Summary for Windsor, Ontario, August 1962, Department of Transportation and Communications, Canada) on July 26 and similar low temperatures were recorded at Chatham.

TABLE IV. Summer precipitation for selected years at Chatham, Ontario

Month	Year				
	1949	1954	1955	1963	60-year average
June	3.6	1.2	2.0	1.2	2.6
July	2.1	1.5	2.2	2.7	2.8
August	2.4	0.8	2.9	1.6	2.5
Total	8.1	3.5	7.1	5.5	7.9

TABLE V. Average summer temperature for selected years at Chatham, Ontario

Month	Year									
	1949		1954		1955		1963		60-year average	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
June	82	62	80	60	78	58	79	58	79	56
July	84	66	82	60	87	68	83	61	84	61
August	81	63	80	60	83	67	77	58	82	59

From the above discussion, it is apparent that a season favorable for corn development is also a season for the establishment of a high corn borer population if conditions are also favorable for oviposition. In an earlier paper (Wressell, 1972), I demonstrated that a heavy flight of moths did not necessarily mean a high borer infestation. It would appear that a high, but not extreme, night temperature, with plentiful rainfall at frequent intervals rather than downpours, are prime requisites for borer establishment and development. If these conditions are met, even a small overwintering generation may give rise to a large field infestation.

Area of Second Generation

As mentioned earlier, 10 infested plants were dissected in each field examined in the survey and the borer population thus found. A record was kept of the different instars, as well as the pupal cases. Because the survey was taken in late summer and early fall, any larvae of the first and second instars undoubtedly belonged to the second generation. However, larvae of the third or fourth instar could conceivably belong to either late first or early second generations. Consequently, it was not possible to estimate the percentage of each generation from field to field. It was possible to ascertain the distribution of the second generation. The highest concentration is in the Leamington region (Figure 1). As one advances northward and eastward, evidences of second-generation borers become sparser, depending on the season. It can be stated categorically, however, that the entire survey area is in the two-generation zone. For the 19-year period, the figures in parentheses, after each county, show the number of years when evidence of pupae was found during the survey: Essex (19), Kent (18), Elgin (17), Lambton (15), Middlesex (13). In Middlesex, pupae were found as early as 1949, and in the final year of the survey, 1964.

Conclusions

During the 19 years when this survey was in progress, there were periods of high infestation followed by years of very low infestation. Rainfall and temperature appeared to have an equal effect on the degree of infestation which, like the weather, was cyclical in nature. Examination of earlier data (1926 to 1945), compiled mainly by Thompson (1940) and based on stalk infestation counts only, shows the same cyclical trend. In 1926 and 1940, high counts were recorded in the survey area — 75% (1926) and 71% (1940), while only 7% was recorded in 1934, which was a drought year. In Michigan (state records), high borer populations were recorded in 1940, and very low populations in 1934. Generally speaking, the greatest concentration of borer populations was in the southern part of Essex County but, in drought years and when summer temperatures were low, particularly at night, there was a dramatic drop in the population. Given favorable conditions, the borer can increase in numbers quickly as it did in Middlesex in 1958 and 1959. Because this insect depends so completely on critical weather factors, forecasts cannot be made about probable damage. In any one year damage will vary, not only from county to county, but even from field to field within townships. While a constant vigilance must be maintained against this insect, it is only rarely that a control needs to be applied in grain corn.

Acknowledgements

Many people assisted in gathering data during the period of this survey. The writer wishes to thank all those who were associated with this study; their names are legion. Special thanks must be given to Mr. G.R. Driscoll, who is now stationed at the Research Institute, Agriculture Canada, London, Ontario. He was responsible for organizing many of the field parties, and supervising much of the work in the field.

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ALDICARB: A SYSTEMIC SOIL PESTICIDE USEFUL FOR ESTABLISHING APPLE PLANTINGS

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Abstract

Aldicarb (10% granular) applied in an 18-inch band around newly planted McIntosh apple trees twice a season for three successive years gave excellent control of the root-lesion nematode, *Pratylenchus penetrans* Cobb., good to fair control of European red mites, *Panonychus ulmi* (Koch), apple aphids, *Aphis pomi* De Geer, and some reduction in numbers of leafhoppers and leaf-feeding caterpillars. Trees treated at rates of 16.7 or 11.2 g of 10% aldicarb per cm of trunk diameter for the three years had increased terminal growth and trunk diameter compared to control trees. Aldicarb is a promising soil treatment for establishment of new apple plantings.

* * * * * *

Introduction

Aldicarb, a systemic compound with a wide spectrum of activity, has been under development since 1962. It is effective as a 10% granular formulation against insect and mite pests of citrus, pome fruit, cotton, vegetable and ornamental crops (Asquith 1967, Coppedge *et al.* 1967, Tashiro *et al.* 1969, Maitlen *et al.* 1970, Sleesman 1971). Aldicarb at 5 and 10 lb/acre, controls the root-lesion nematode *Pratylenchus penetrans* Cobb on easter Lily (Maggenti *et al.* 1970). Asquith (1967) showed that aldicarb controlled European red mite, *Panonychus ulmi* (Koch), the two-spotted spider mite, *Tetranychus urticae* Koch, and the apple aphid, *Aphis pomi* DeGeer, when applied in a band around 15-year-old apple trees in sod. Maitlen *et al.* (1970) reported that 1 lb of 10% aldicarb applied to soil around mature apple trees May 9 controlled *P. ulmi* and *T. urticae* until the end of July and 2 lbs gave control to mid-August.

Beavers *et al.* (1970) concluded that use of aldicarb would likely be limited to young nonbearing fruit trees for two reasons. First, aldicarb controlled mites and insects better on 1 to 4-year-old citrus trees than on mature trees, possibly because rate of translocation in the latter was slower, especially when aldicarb was applied as a side-dressing. Second, residues of aldicarb sulfoxide have been found in orange fruits, up to 100 days after treatment and in apples up to 143 days after treatment (Maitlen *et al.* 1970).

This is a report of experiments with aldicarb to control mites, insects and root-lesion nematodes on newly planted apple trees.

Materials and Methods

In the spring of 1968, thirty one-year-old McIntosh apple trees on standard rootstock were planted in a 7 ft. x 7 ft. spacing in Vineland silt loam soil. Aldicarb (10% granular) was broadcast and raked into the soil in an 18-inch band around the trunk of each tree and one gallon of water was then applied per tree. The quantities of aldicarb applied and the frequency and time of application for the various treatments are shown in Table 1. Treatments were applied to single trees

TABLE I. Dates and rates of aldicarb soil treatments to newly-planted McIntosh trees during 1968, 1969 and 1970.

	Aldicarb (10%) g per cm trunk dia.					
	1968		1969		1970	
Treatment[a]	July 24	Aug. 9	May 21	June 9	May 21	June 9
1	16.7	16.7	16.7	16.7	16.7	16.7
2	11.2	11.2	11.2	11.2	11.2	11.2
3	5.6	5.6	5.6	5.6	5.6	5.6
4	0	0	8.4	8.4	8.4	8.4
5	22.3	22.3	0	0	0	0
6 Untreated	0	0	0	0	0	0

[a]Five replicate trees per treatment.

TABLE II. Control of European red mite and apple aphid, on young McIntosh trees, by aldicarb soil treatment in 1970.

	Av. no. of mites and eggs per leaf[b]					
Treatment[a]	Pre-treatment		Post-treatment		Av. aphid rating[c]	
	May 21	June 9	June 16	July 13	July 9	Aug. 10
1	1	1	0.3	8.0	1	1
2	1	0.3	0.7	9.0	1	1
3	0.5	1.0	4.7	28.0	1.7	1
4	0.3	1.3	3.7	16.3	1	1
5	0.3	0.8	2.2	27.7	2.8	2.0
6 Untreated	0.1	0.1	0.3	18.4	3.2	3.7

[a]TABLE I

[b]Av. of 10 leaves from each of 5 trees per treatment.

[c]Av. of 5 terminals per tree, 25 per treatment; rating, 0 = nil, 1 = <5, 2 = 6-25, 3 = 26-50, 4 = >50.

randomized within plots and plots were replicated five times. The 1968 treatments were applied 3 months after the trees were planted.

Each tree was artificially infested with a laboratory strain of *P. ulmi* during early May of 1968 and 1969 to assure a viable population. To assess the effect of aldicarb on the mites, a sample of 50 leaves per treatment was collected (10 leaves from each of 5 trees) immediately before the first application and at 7-14 day intervals during the season thereafter. Mites and eggs were brushed from the leaves onto glass plates and counted under a stereoscopic microscope (Henderson and McBurnie 1943). Other apple pests on the plates were also recorded. Aphid populations were assessed by examining 5 random terminals per tree, 25 per treatment, and rated (the average number) as 0 = nil, 1 = <5 on any leaf, 2 = 6-25 per 2-3 leaves, 3 = 26-50 per leaf, 4 = >50 per leaf, and stem infested (Table II).

All trees were left unpruned during the experimental period and growth was evaluated in 1970 by measuring trunk diameter 6 inches above ground and calculating the cross-sectional area. In addition the mean length of 5 terminal branches selected at random from each tree was determined. The trees were then lifted and the soil and roots analysed for the root-lesion nematode, *P. penetrans*. Nematodes were extracted from the soil for a one-week period by a modified

Oostenbrink method (Townshend 1963) and were extracted from the roots for a two-week period by placing washed feeder roots in polyethylene bags containing 50 ml of water.

Results and Discussion

Despite artificial infestation of the trees, the numbers of mites remained below 40 mites/leaf for all treatments during the three seasons. In 1968 (Aug. 22) there were approximately 6 motile mites per leaf on each of the leaf samples from the 22.3 g, 16.7 g, and 11.2 g treatments, whereas the numbers per leaf were 14 and 30 for the 5.6 g treatment and untreated trees respectively.

There were fewer mites in 1969 and by Sept. 5 there were less than 0.03 mites/leaf in the 16.7 and 11.2 g aldicarb treatments. Samples from each of the other treatments had fewer than 4 per leaf. Treatments 4 and 5 (Table I) were to evaluate the importance of applications during the first year of planting. The highest numbers of mites were on trees treated only the first season. The earlier applications of aldicarb in 1969 possibly resulted in increased translocation and effectiveness and may account for the lower mite populations in 1969 with all treatments. Maitlen *et al.* (1970) reported increased uptake of aldicarb with early season (May) applications.

In 1970 the numbers of mites increased during July (Table II) and control was satisfactory only where aldicarb was applied each season at the 16.7 and 11.2 g rate. The highest rate of aldicarb applied only during the first season (Treatment 5) showed no residual toxicity in 1969 or 1970. Hence for effective mite control aldicarb must be applied each year. The relatively low mite numbers on untreated trees (Table II) in 1970 resulted from the extremely poor condition of the foliage which was damaged by mites, aphids, leafhoppers, leaf-feeding caterpillars, and sooty blotch fungus. Leaves from the control trees were also smaller than those on all treated trees. There was no residual toxicity by Aug. 4 and mite numbers increased to 37 per leaf in plots treated at the 5.6 g rate.

Predatory phytoseiid mites were reduced in numbers by the aldicarb treatments. In 1969 none were present by Sept. 5, on 50-leaf samples from trees treated at the two highest rates; there were fewer than 1 mite/leaf in all other treatments whereas 26 were found on untreated leaves. In 1970 phytoseiids were scarcer; 6 were found on 300 untreated leaves, compared to only 1 or 2 on leaves from all other treatments. Predatory insects were present only in trace numbers during the three seasons.

TABLE III. Control of the root-lesion nematode, *Pratylenchus penetrans*, on McIntosh trees, by aldicarb soil treatment in 1970.

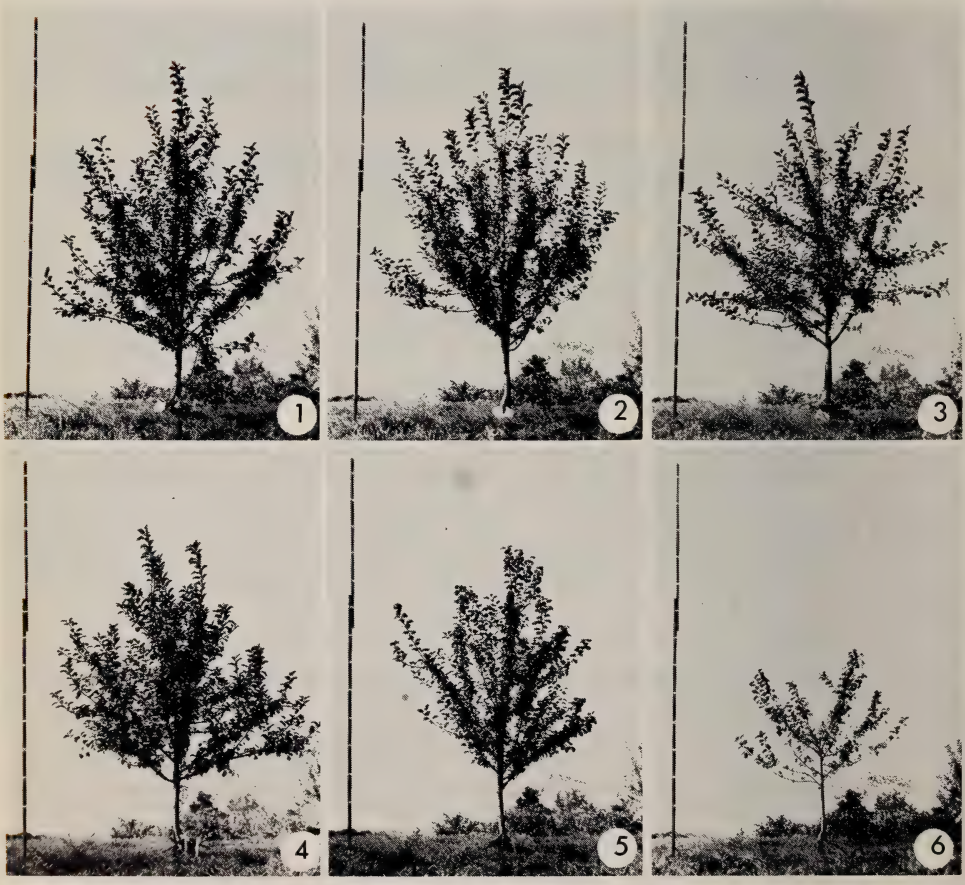
	Av. no. of *P. penetrans*[b] per	
Treatment[a]	50 g of soil	g of dried feeder root
1	7	20
2	9	14
3	7	60
4	9	16
5	98	1767
6 Untreated	135	2433

[a]TABLE I

[b]Av. for 5 replicate trees per treatment.

The 5.6 g rate of aldicarb controlled aphids the season of application but, as with mites, there was no control the following year (Table II). The two highest rates of aldicarb applied each season provided some reduction in numbers of leafhoppers, leaf-feeding caterpillars and other minor pests.

There was no significant difference between the 1968 treatment of aldicarb at the 22.3 g rate and the untreated controls, in the number of root-lesion nematodes in 1970 (Table III). Rates as low as 5.6 g of aldicarb applied each season or 8.4 g applied during 1969 and 1970 gave over 95% reduction of root-lesion nematodes in the feeder roots in 1970.



FIGURES 1-6 Effect of aldicarb at different rates on growth of trees three years after planting: Figs. 1,2,3, treated twice per season for 3 years at 16.7, 11.2, 5.6 g per cm of trunk dia. respectively; Fig. 4, treated 8.4 g per cm of trunk dia. twice per season 1969, 1970; Fig. 5, treated twice 1968 only at 22.3 g per cm of trunk dia.; Fig. 6, untreated check. Height marker graduated in feet.

The increased terminal growth and better condition of the foliage of the trees in 1969 and 1970 is evidence of the value of aldicarb at the 16.7 and 11.2 g rates in controlling the numerous apple pests. Statistical analyses of measurement data indicated all treatments differed from the control with no significant differences between treatments. The mean terminal growth was however higher for the higher rates of aldicarb; 73.0, 71.8, and 65.8 for the 16.7, 11.2, and 5.6 g rates respectively (Table IV Figs. 1-6).

TABLE IV. GROWTH of young McIntosh trees, third season after planting and soil treatment with aldicarb.

Treatment[a]	Av. terminal growth (cm)	Av. trunk cross-section (cm^2)
1	73.0[b]	13.8[c]
2	71.8	14.9
3	65.8	13.4
4	65.3	11.3
5	63.4	11.5
6 Untreated	51.5	5.9

[a]TABLE I

[b]LSD 0.05 = 12.35

[c]LSD 0.05 = 2.39

It is probable that the large reduction in nematode populations and the control of aphids due to aldicarb contributed most to increased tree vigor, and terminal growth.

Our results indicate that aldicarb applied twice a season will provide a simple effective control program for apple pests during the establishment period of new apple plantings. At present, cost of controlling apple pests on young trees with regular spray programs and with preplant nematicides can be prohibitive.

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THE DEVELOPMENT OF PROCEDURES FOR THE ASSESSMENT AND INTERPRETATION OF SOME METHODS OF AUTOCIDAL INSECT CONTROL.

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Abstract

Progress is reported for studies on the biochemical identification of genetic strains (or genotypes) of insects, the detection of insemination in females by autoradiography and autosomal (somatic) effects of chemosterilants. While these studies were conducted with midges (Chironomidae) and mosquitoes (Culicidae), the methods are probably applicable to other insect groups as well.

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Introduction

Autocidal insect control can be described in general terms as the destruction of pest insects through the use of the insects themselves. The most promising methods include the manipulation of genetic processes in insect populations (e.g. the introduction of deleterious genes); and the introduction into populations of individuals sterilized by radiation or chemosterilant compounds. As fundamental and developmental studies have proceeded, however, they have continued to point out an increasing number of gaps in our understanding of certain basic and necessary aspects of insect ecology, behaviour and physiology. The closing of many of these gaps will be necessary before autocidal methods can be applied to pest problems in an effective, efficient and interpretable manner.

A rather modest program has begun in our laboratory to investigate a few of the basic problems relating to the assessment and interpretation of some procedures used in autocidal control. While most of the studies to date have been conducted with Nematocera (particularly chironomid midges and mosquitoes), it is quite possible that the broad findings and principles developed will have application to other insect groups as well. The three aspects of the program discussed in this paper are:

1. The identification by biochemical techniques of genetic strains (or genotypes) in populations.
2. The detection of insemination in female insects by the use of radioactive labelling of spermatozoa.
3. The investigation of autosomal (or somatic) effects of chemosterilant compounds.

The Identification of Genetic Strains or Genotypes

The main objective of these investigations has been to develop methods for the identification of different genotypes in insect populations through the use of electrophoresis and serological techniques. Such methods would have obvious value in a program of population management involving the introduction of deleterious genes and where the differences among genetic strains are not signalled by morphological characters.

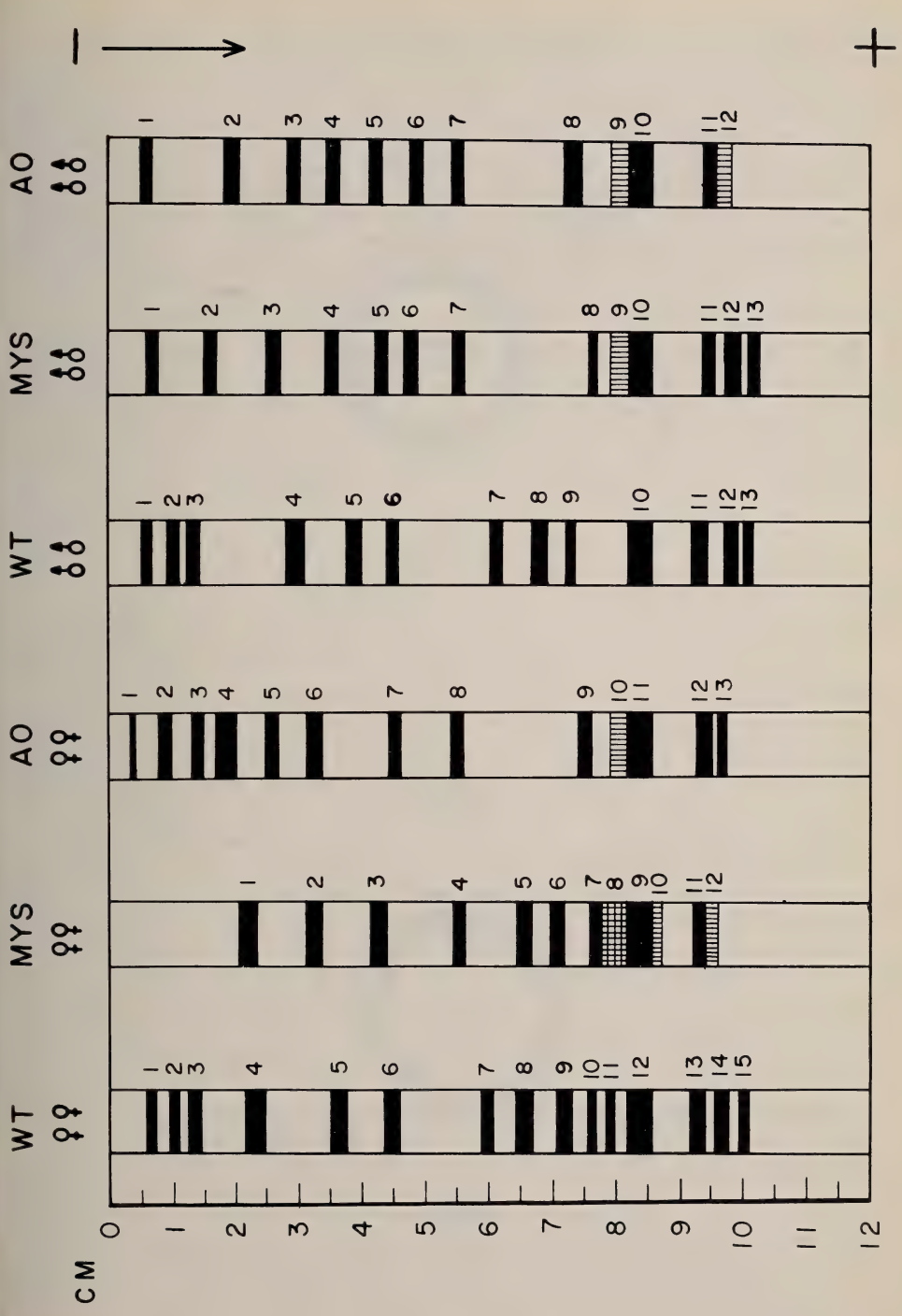

FIGURE 1. Drawings of gels showing protein patterns from adult males and females of three genetic strains of *Aedes aegypti*. The numbers beside each gel are only to designate the serial positions of the fractions in each strain. Comparative mobilities are determined with reference to the metric scale on the left.

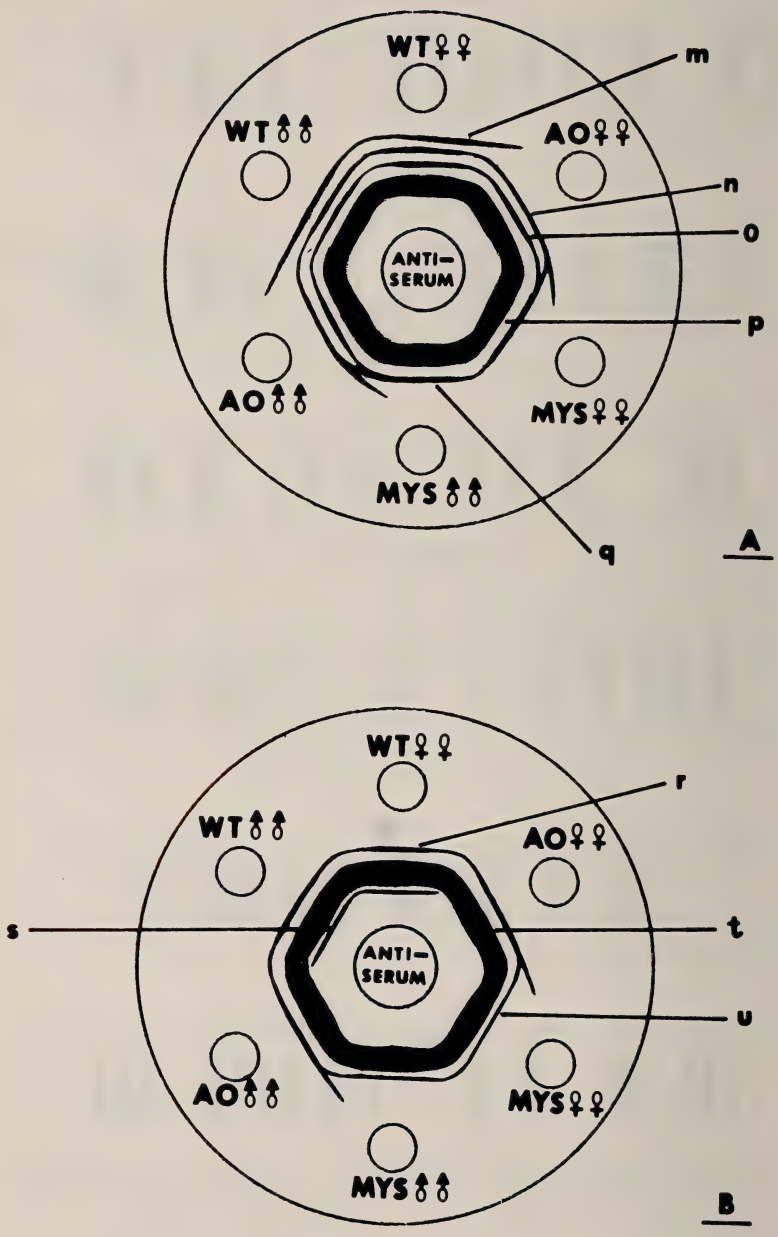

FIGURE 2. Drawings of Ouchterlony plates showing immunodiffusion reactions of protein extracts from three different strains of *Aedes aegypti*. Reactions in A are with anti-WT ♂♂ serum; in B with anti WT ♀♀ serum. Indicator lines show precipitate bands which are unique to the WT strain (e.g. *m* and *s*), and those which are identical (e.g. *p*) or partially identical (e.g. *o*, *q*, *u*) among the strains.

Initial investigations were conducted with three genetic strains of the mosquito, *Aedes aegypti* (L.). Descriptions of two of the strains, MYS (silver thorax) and AO (gold) were given previously (Craig and Hickey, 1967; McClelland, 1967). The other strain, WT—Queen's, was of similar origin to the NIH strain described by Craig and Hickey (1967) and mainly conformed to the morphological features given by these authors. It should be stressed, however, that no records of the genetic variability in populations of our strain have been kept since its initial colonization at Queen's University in 1951. It is, therefore, reasonable to suspect that there has been considerable genetic divergence from the original NIH stock. The three strains are morphologically distinguishable by the color and patterns of mesonotal scales.

For comparisons of the strains by electrophoresis, saline extracts of proteins were prepared from pools of adult males or adult females of each strain (0.4 g of mosquitoes in 3 ml of 0.13M NaCl in 0.01M phosphate buffer, pH 7). All adults used were 72 hrs. old. Extracts were standardized to 10 mg protein/ml and subjected to electrophoresis in cylindrical polyacrylamide gels in Tris-glycine-HCl buffer (pH 8.1) (Clarke, 1964). Each sample to be fractionated consisted of 0.2 ml of a mixture of extract and a 30% aqueous solution of sucrose (3:1). Upon completion of electrophoresis, proteins in each gel were fixed with 12.5% trichloroacetic acid (Chrambach *et al.*, 1967) and then, after rinsing, were stained with 0.1% Naphthol Blue-black in 7% acetic acid (Clarke, 1964).

The results obtained from electrophoresis of protein extracts from pooled mosquitoes (Fig. 1) indicated differences among strains and differences between sexes within strains. Several replications of the tests yielded essentially the same results with only minor variations in the mobilities of some proteins.

Similarly, immunodiffusion tests performed with the extracts from different strains showed that characteristic patterns of precipitate were detectable for each strain (Fig. 2). The tests were performed in standard Ouchterlony plates (Nutritional Biochemicals, Cleveland, Ohio) with appropriate antisera prepared in rabbits by the injection of the extracts (Collins and Downe, 1970; Downe, 1962).

The specific features of both electrophoresis and serological tests were combined to provide a method for the identification of individual insects. The method was modified from that reported previously for the study of tissue proteins (Collins and Downe, 1970). The extract of a "reference strain" was simultaneously electrophoresed in duplicate polyacrylamide gels. One gel was fixed and stained for use as a "map". Segments were cut from a second, unfixed, unstained gel using the stained gel map as a guide to the position of the proteins to be removed. A series of preliminary immunodiffusion tests indicated which of the various gel segments gave the most specific serological tests. A gel segment containing a specific protein (or proteins) for the "reference strain" was placed in a peripheral well of an immunodiffusion plate. "Unknown" individual mosquitoes (that had been crushed and extr acted in 0.2 ml saline) were placed in wells adjacent to the reference. An unknown was identified as belonging to the reference strain when the extract from it reacted with the antiserum to produce a band of precipitate identical to that given by the reference (Fig. 3). A series of "unknowns" was prepared from the three strains by one of a pair of workers. The other worker performing the identification tests was unaware of the strain identity of the specimens. Of 130 unknowns tested, 124 were correctly identified as to their strain of origin.

It would appear, therefore, that the methods are sufficiently accurate to warrant further investigation. Additional studies on the identification of *Aedes mascarensis* MacGregor, *A. aegypti* and their hybrids, and with autogenous and anautogenous strains of *Aedes atropalpus* (Coq.) gave similarly encouraging results. Other authors

have also reported demonstrable protein differences between strains of the same species of mosquito (Briegel, 1972; Freyvogel and McClelland, 1969). That infraspecific differences in other families and orders of insects can be demonstrated by electrophoresis and/or serology has also been shown by a number of authors (e.g. Marty and Zalta, 1968; Nigam and Musgrave, 1964; Simon, 1969). While the procedures involved cannot yet be considered to be routine, it is most probable that they could be refined and applied to identification problems in many programs for the "genetic control" of various pest insects.

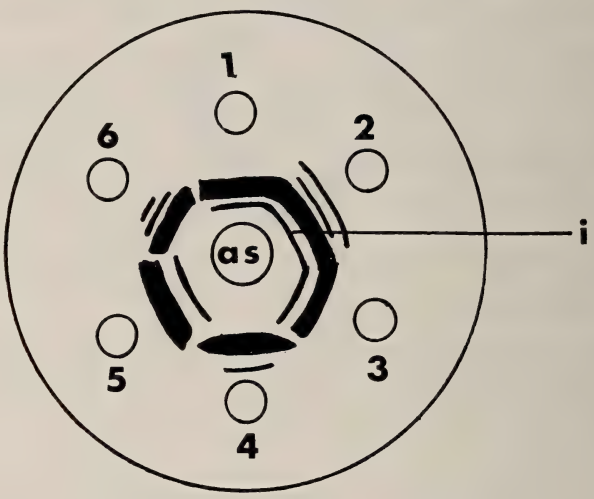

FIGURE 3. Drawing of Ouchterlony plate showing identification of unknown female mosquitoes by immunodiffusion with anti-WT ♀♀ serum (centre well). Reference protein fractionated by electrophoresis of WT ♀♀ extract is in wells 1, 3 and 5. Extracts of individual unknowns are in wells 2, 4 and 6. The unknown in well no. 2 can be identified as belonging to the WT strain since the characteristic band of precipitate (i) has developed in the reaction with the antiserum. The i-band cannot be seen in the reactions of other unknowns and they are not, therefore, of the WT strain.

Studies on Mating and Insemination

Insect mating (or, more specifically, the insemination of females by males) is the key activity in most programs of autocidal control. Information concerning the epigamic behaviour, the number of inseminations conferred by individual males, the number of times a female is receptive to insemination, the environmental and physiological factors affecting insemination frequency is all of obvious importance. There is a paucity of such information for most insect species which is, in part, caused by the lack of convenient or precise criteria for the evaluation of mating performance. For example, the insemination of females of many insect species can only be reliably determined by the time-consuming and often difficult microscopic detection of sperm in the dissected reproductive system.

The insect employed for most of our studies on insect mating has been the midge, *Chironomus riparius* Meigen. Some of the features concerning the mating habits of this insect were reported previously (Caspary and Downe, 1971; Downe, 1973; Downe and Caspary, 1973). *C. riparius* is readily reared in the laboratory and the adults exhibit a predictable series of behavioural events leading to mating in swarms. Mating is markedly periodic and may be controlled by a true rhythm. The adult life of both sexes is only 3 to 4 days.

Investigations of insemination in *C. riparius* were performed using males in which the sperm was labelled with adenine-8-C^{14}. The males were labelled when second-instar larvae by adding one μ Ci of adenine-8-C^{14} to each 40 ml of sterile rearing medium. Once the adult males emerged they were allowed to swarm and mate with unlabelled females under a variety of experimental conditions. Insemination of females was detected by autoradiography. The females were crushed on clean, glass slides, dried in air and the slides placed in film holders with a sheet of X-ray film (Kodak "no-screen"). After a 14-day exposure period, films were developed in Dektol and fixed by standard procedures. Inseminated females produced conspicuous light spots on the film.

The results of numerous trials indicated that this method was at least as accurate for the detection of insemination as the more tedious microscopic examination of dissected spermathecae. Labelled males were as competitive in mating as unlabelled ones and no adverse effects from the labelling were observed insofar as longevity and general activity were concerned. The details of results from these and other studies on matings among genetic strains of *A. aegypti* have been described elsewhere (Downe, 1973; Downe *et al.*, 1973).

Jacob and Sirlin (1958) added adenine-8-C^{14} to the larval rearing medium to label the sperm of male *Drosophila melanogaster*. The same authors also labelled the sperm of male spider beetles, *Ptinus clavipes* Panzer by injections of the same tracer compound. Clearly it is most convenient to have the insects ingest the tracer and recently Smith and Boudreaux (1972) reported an elegant method for labelling the sperm of male spider mites (*Tetranychus* spp.) by first introducing tritiated thymidine into the host plant. Thus, it would appear that the procedures for the labelling of sperm with radioactive materials are applicable to a number of kinds of insects and the methods are of great potential value in assessing insemination rates in insect populations.

The Autosomal Effects of Chemosterilants

The provocative prospect of reducing natural insect populations by the chemical sterilization of one or both sexes has stimulated much interest and research. The principal concepts and methodologies have been reviewed by a number of authors (e.g. Campion, 1972; Knipling, 1968; Proverbs, 1969). Several reports have indicated that the effects of some chemosterilants are not limited to the reproductive systems in insects but may also produce so-called autosomal (or somatic) effects as well. Aberrant or deterimental effects after treatment with chemosterilants have been observed in responses to sex pheromones (Henneberry *et al.*, 1966), epigamic behaviour (Dame *et al.*, 1964), feeding habits (Judson, 1967) and digestion (Akov, 1965). There is a need for more precise information on the extent of such autosomal effects in relation to the types and dosages of chemosterilants that produce them, and the species of insects that are affected.

Our studies on chemosterilants are in preliminary stages and initial investigations concerned sterilization of male *Chironomus riparius* with apholate. For chemosterilization, first- and second-instar larvae were placed in a rearing medium containing 20 ppm of apholate (Powell and Craig, 1969). Adenine-8-C^{14} was added to the medium as described earlier in this paper. Batches of 50 newly-emerged males which were chemosterilized and labelled with C^{14} were placed in cages with equal numbers of unlabelled, virgin females. Observations during the daily swarming periods revealed that treated males displayed unusual swarming behaviour. They maintained a steady flight around the cage and only occasionally paused to hover over the swarm marker. No coupling of these males with females was observed. Autoradiographs of females that were removed from cages after the swarming

periods indicated that they had not been inseminated by the chemosterilized males. In simultaneous tests with virgin females and labelled but fertile males swarming of males followed the typical sequence of events described by Downe and Caspary (1973). Autoradiographs of the females from these control tests revealed that 90% were inseminated.

The provisional interpretation of these results is that chemosterilization with apholate affected the normal epigamic behaviour of males so that they were unable to perform their mating function. Powell and Craig (1969) reported that male *Aedes aegypti* that had been treated with apholate as larvae would mate nearly as frequently as untreated controls. These authors found, however, that accessory glands in the reproductive systems of treated males were about half as large as those in untreated controls. Treated males were much less efficient in rendering females monogamous. Such findings as these raise doubts as to the value of larval treatment with apholate (and perhaps similar compounds) in the control of nematocerans by the release of chemosterilized males. On the other hand, the results do suggest that apholate and other such alkylating agents may be valuable research tools in the areas of insect behaviour and physiology.

The chemosterilant concept can be extended to include such naturally occurring compounds as "matrone" (Craig, 1967; Fuchs et al., 1969). This substance is produced by the male accessory glands of mosquitoes and, when transferred in the semen, renders the females monogamous. Our studies have demonstrated that a similar substance exists in males of *Chironomus riparius*. The swarming behaviour of females injected with extracts of male accessory glands was observed to be different from that of uninjected virgins (Downe, 1973). Other studies on matrone from mosquitoes have indicated that it influences the rate of digestion of blood meals in females (Downe, *in litt.*). An appreciation of such natural mechanisms is of value in planning autocidal programs. Moreover, these mechanisms in themselves may offer much potential promise as methods of insect control.

Conclusions

The subjects discussed in this paper represent a few of the many fundamental aspects of autocidal control which require investigation. A main objective of all such studies should be to develop utilitarian procedures which can be applied to the evaluation and interpretation of a wide spectrum of problems and several types of insects. Such procedures would provide baselines for the comparative assessment of the achievements or difficulties in different programs.

The justification for fundamental studies is based upon the assumption that autocidal methods of insect control are feasible and practical. At the present time autocidal methods have found practical application in a relatively few types of pest problems. That they can be extended to a wider range of insects and problems could be determined, at least in part, by the outcome of basic studies on methodologies.

Acknowledgments

This work was financially supported by grants from the National Research Council of Canada and the Queen's University Research Fund. Post-doctoral Fellows, graduate students and research assistants have contributed much to the studies on procedures, the performance of tests and the formulation of ideas discussed in this paper. In particular, I thank Drs. J.V. Collins and E.C. Igbokwe; Mrs. K. Steel; Misses L. Hubbard, J. Hyatt and M. Newkirk; Messrs. V.G. Caspary, G. Egger, F. Kwan, B. Watts and C.H. Yang. Drs. G. Bracken, A.W.A. Brown, D.T. Canvin, G.B. Craig Jr. and B.G. Loughton have generously provided insect cultures or other materials for these studies.

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CONTROL OF BOTRYTIS ROT IN STRAWBERRIES WITH CAPTAN APPLIED FROM A BOOM SPRAYER WITH DROP ARMS.

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Abstract

Gray mould, caused by the fungus *Botrytis cinerea* Pers. ex Fr., reduces the yield and quality of strawberries in wet seasons as much as 20-50% despite applications of fungicide by air-blast and boom-type sprayers. To improve application efficiency, five different sets of nozzles attached to a boom were tested; two ground speeds and two concentrations of captan were used. Half the nozzles were placed near ground level on rubber hoses to direct spray laterally into the plants. By means of fluorescent dye ratings, fluorometric analyses, and rot counts, a nozzle set was found that improved both coverage and rot control.

* * * * * *

Introduction

Gray mould or botrytis rot of strawberries, caused by the fungus *Botrytis cinerea,* Pers. ex Fr. annually reduces the yield and quality of the crop in Ontario. In wet seasons, which favour the fungus, the loss may reach 20-50%, in spite of application of the recommended fungicide, captan.

The disease often appears early in the season as a blossom blight, later spreading to the calyx, to the berry beneath the infected sepals, and even to the sides of the berries where they touch soil or other damp surfaces. After early blossom blight or fruit infection, the disease frequently progresses downward through the pedicel to the main fruit stem, so that finally most of the fruit cluster is destroyed. Timing and placement of fungicide, and the wetness, depth, and density of foliage determine the severity of the disease.

Sprays in Ontario are applied with three kinds of equipment: 1) hydraulic boom-type sprayers with high pressure; 2) boom-type compressed air sprayers with air-shear nozzles; 3) air-blast machines fitted with row crop attachments that blow spray across 5-7 rows.

This paper reports results on spray coverages, chemical deposits, and rot control when five different nozzle assemblages were used on a single hydraulic boom.

Materials and Methods

The experiment consisted of ten 150 metre rows of Early Dawn strawberries divided for sampling into 2 plots, each of 4 replicates. The area was situated in the middle of a 10-acre field of strawberries. Each plot was a swath sprayed simultaneously with 5 nozzle assemblages on a single boom. Eleven sprays were applied during the season and coincided with those applied to the whole acreage by the grower.

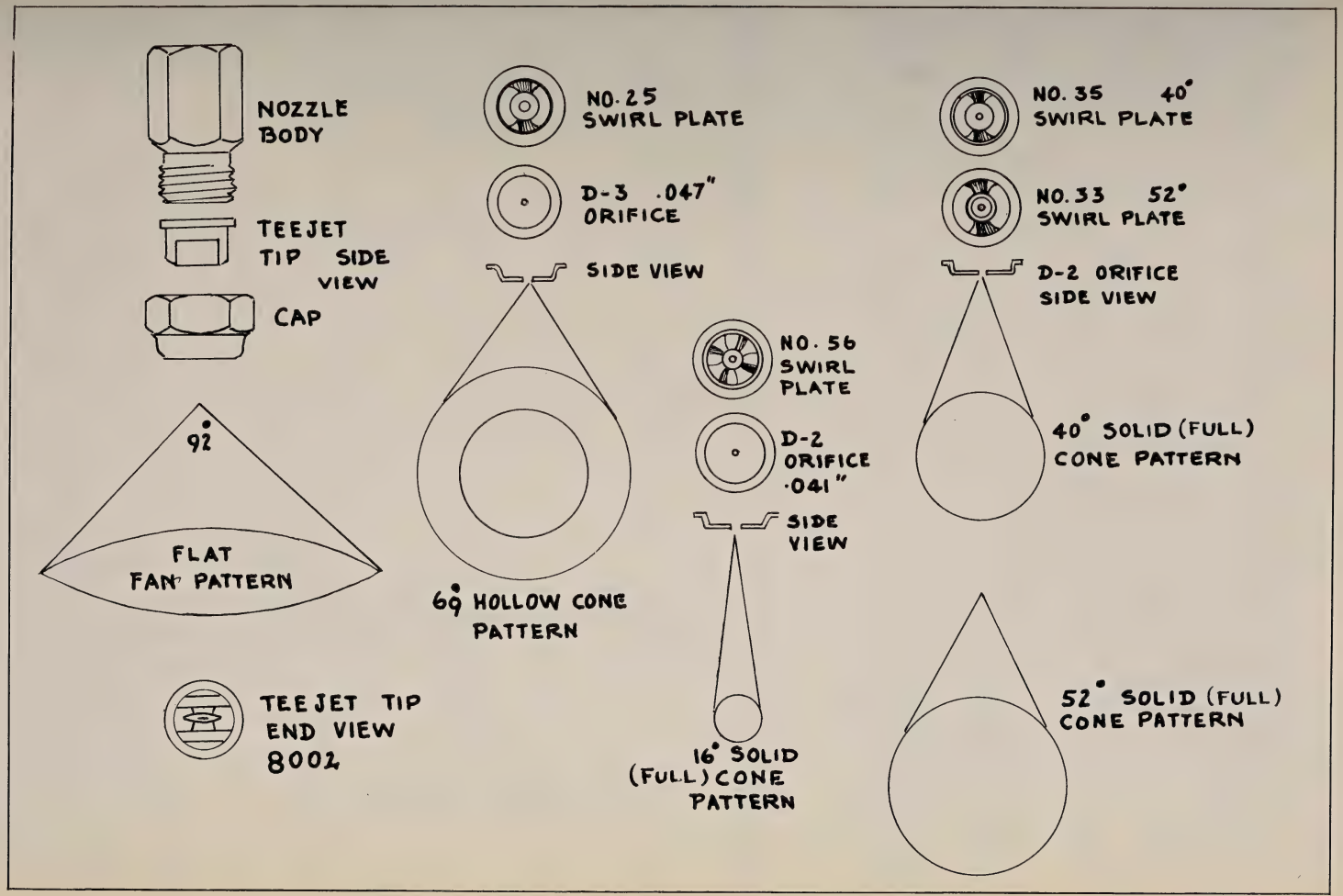

FIGURE 1 Illustrations of various nozzle components, patterns, and spray angles used on the experimental spray boom.

Sprayer

A Rittenhouse self-powered Whirlwind sprayer with a 300 gallon tank, 20 gallon per minute high-pressure pump, and a 17-foot boom designed to cover 5 rows spaced 42 inches apart, was used. Four nozzles were directed toward each row, two on single swivels, 21 inches apart, 3 inches below the boom, and two on single swivels at the ends of rubber hose drop-arms. All nozzles were directed toward the centre of the row of plants (Fig. 2-5). Under the 300 p.s.i. operating pressure, the ends of the drop arms were forced out to a width of 26 inches, an inch to either side of the 24 inch row. For this test, 5 sets of nozzles with different outputs and spray angles were attached to the single boom. (Fig. 1, Table I).

The boom was lowered until the ends of the drop-arms touched the straw mulch between the rows. The bottom nozzles could thereby drive laterally and slightly upwards into the plants where leafy obstruction was minimal. Four of the first five sprays were applied at 1 1/2 miles per hour (m.p.h.), the remaining 7 at 3 m.p.h. Immediately after rains, and twice in light rain, sprays with half the volume per hectare and doubled concentrations of captan were applied at 3 m.p.h. to cover the fields quickly. Drift of spray from row to row was negligible and did not affect the coverage with the foliage from which the samples were taken.

TABLE I. Characteristics of five different nozzle assemblages on a single hydraulic boom used to spray strawberries.

Nozzle*			Spray droplet	Volume gal. per acre	
		Angle	mass median	applied at speeds of	
No.	Type	of spray	diameter, in microns	1.5 m.p.h.	3 m.p.h.
	Flat-fan				
1	#8002	92°	350	160	80
	Flat-fan				
2	#8004	90°	380	320	160
	Orifice D-3				
3	Swirl#25	69°	215	145	72.5
	Orifice D-2				
4	Swirl#56	16°	280	190	95
	Orifice D-2				
5	Swirl#33	52°	225	185	92.5
	Swirl	40°	240		

* Spraying Systems Co. c/o John Brooks & Co. Ltd.,
255 Hymus Blvd.,
Pointe Claire, Quebec

Materials

Captan 50 WP (50% wettable powder) was applied at a concentration of 3 lbs/100 gal (3 g/l) at 1 1/2 mph (2.4 km/hr) and 6 lbs/100 gal at 3 mph. Ideally all nozzles should have been tested with the same rate of chemical application but this could not be achieved. The coverage achieved by each set of nozzles, however, was not affected by the quantity of captan applied per hectare. Phosphor 2283 dye tracer, a manganese-activated zinc orthosilicate (excited at 2537 A and fluorescing green at 5270 A) was added to the spray at a rate of 3 g/gal (0.66 g/l).

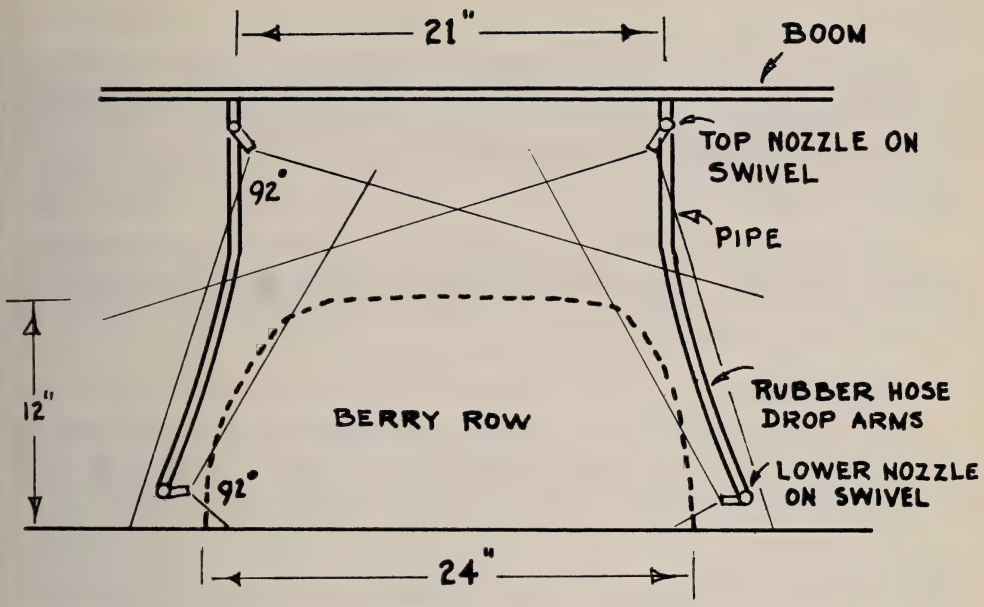

FIGURE 2 Nozzle arrangement on the spray boom. Angle of spray for flat-fan nozzles 8002 and 8004 (No. 1 and No. 2 in Table I).

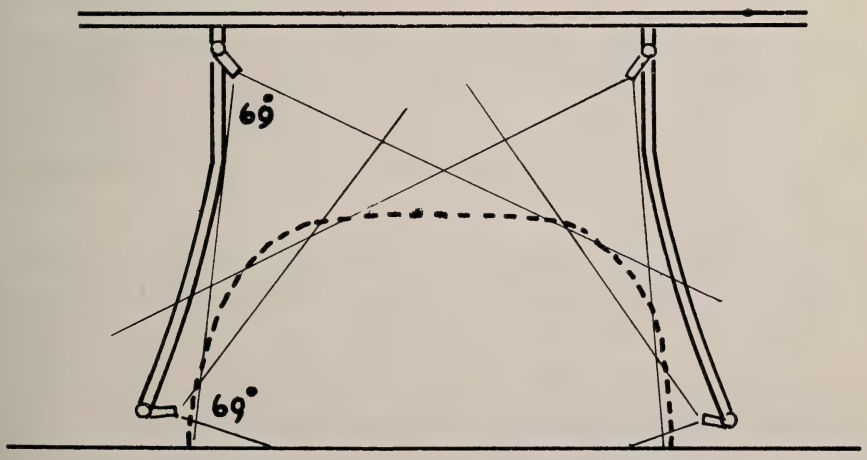

FIGURE 3 Nozzle arrangement and spray angles for hollow-cone nozzle (No. 3 in Table I).

Sampling of Leaves

Four replicate samples of 25 leaflets were picked from the middle inside of each row and examined under short wave ultra-violet light (2537 A) with a stereoscopic microscope. Ratings of coverage on the lower surfaces of the leaves were made according to the method of Fisher and Hikichi (1971).

Sampling of Fruits

Four replicate samples of 25 fruits, about 1/2″ in diameter, were examined in the same manner as the leaves. Separate ratings were assigned to the calyx and the fruit. Each berry was turned under the U.V. light and an average rating derived from maximum and minimum values.

Sampling of Residues

Strips of green desk blotter (4 1/2″ x 1 1/2″), lightly impregnated with paraffin wax were formed into cylinders and placed over 1 5/16″ dowel pieces fastened to 16″ x 1/4″ iron stakes. Two of these simulated berries per replicate were placed about mid height (6″) within the berry plants; the cylinders were horizontal and parallel to the row. When the spray was dry, the paper cylinders were removed and placed in storage boxes so that deposits would not be altered. For assessment, each strip was fastened to the door cylinder of a Turner model 111 fluorometer and fluorescence values were recorded for 7 positions (each 1.27 cm^2 using a 30x incident light setting and 1% transmission of fluorescent light. Values were converted to micrograms per cm^2 of applied captan and an average value per simulated berry derived. From the eight samples (2 in each of 4 replicates) average values for dye and captan deposits were recorded for each nozzle assemblage.

TABLE II. Relationships between coverage*, deposits, rates emitted, and incidence of botrytis rot in strawberries sprayed with five different nozzle assemblages.

Nozzle No.	Max. % rot	Captan 50 WP applied lb/acre	Captan*** deposits μ g/cm^2 calculated from Phosphor 2283 dye deposits on paper targets		Visual coverage values on berry fruits		Visual coverage values on berry calyces		Visual coverage values on lower leaflet surfaces	
			1.5 mph	3 mph	1.5 mph	3 mph	1.5 mph	3 mph	1.5 mph	3 mph
1	6.62 bc **	4.8	6.39 bc	3.96 b	5.71 b	4.76 b	9.64 a	7.18 c	8.01 ab	6.43 c
2	3.00 a	9.6	12.60 a	8.00 a	6.54 a	5.77 a	9.84 a	8.98 a	8.40 a	7.54 b
3	8.00 c	4.4	3.34 d	1.90 b	5.27 c	4.42 bc	7.20 d	5.90 d	7.33 c	6.01 c
4	11.38 d	5.7	3.26 d	2.01 b	5.12 c	4.19 c	8.32 c	7.99 b	7.61 bc	8.50 a
5	1.63 a	5.6	7.99 b	4.01 b	5.33 bc	4.62 bc	8.97 b	7.21 c	8.12 a	8.58 a

* Values based on a range 1-10 (trace deposit to complete coverage)

** Values followed by the same letter do not differ significantly at the 5% level (Duncan's Multiple Range Test).

*** Concentration of Captan in the test spray was 3 lbs/100 gal. for both 1 1/2 and 3 mph. All other sprays applied by the grower contained 3 lbs/100 gal. for 1 1/2 mph and 6 lbs/100 gal. for 3 mph

Rot Samples

Non-destructive sampling for botrytis rot was done on June 20, June 29, and July 5, 1972. In the first sampling, because of a very low incidence of rot, 400 berries from each replicate were examined *in situ*. In the second and third samplings 100 berries were examined in each replicate plot. Examinations were made before the regular picking so that percentage of rot would not be reduced by the removal of infected berries from the field.

Analyses

All data were subjected to an analysis of variance and significant differences derived by Duncan's multiple range test.

Results and Conclusions

Examination of data in Table II shows the following:

1) Percentage rot values ranged from 1.63 to 11.38 in the treatments.

2) Visual ratings of coverage on receptacles and leaves were all very high, and though there were significant differences among ratings, effective control could be expected at these levels.

3) Visual coverage was lower on fruits than on other plant parts; the lowest rating coincided with the highest rot values, but it was not significantly different from the rating for the lowest rot value. The averaging of maximum and minimum ratings on each berry unfortunately masked the degree of unsprayed or poorly sprayed surface on the berry where infection could occur.

4) Visual ratings were almost all lower for the 3 than for the 1.5 mph applications, but not to the extent expected by halving the volume per acre applied at the higher speed of travel.

5) Full-cone nozzles no. 4 and no. 5 both gave higher coverage at 3 mph than at 1.5 mph despite the reduction in volume per acre.

6) Full-cone nozzle no. 4, while emitting virtually the same volume as full-cone nozzle no. 5 (Table I), deposited only half as much material on the paper targets and allowed seven times as much rot as did no. 5.

7) Flat-fan nozzle no. 1 applied half as much liquid as flat-fan nozzle no. 2 (Table I), deposited correspondingly half as much chemical on the paper targets and allowed twice the amount of rot.

8) Hollow-cone nozzle no. 3 emitted the lowest volume (Table I), deposited the same amount of chemical and provided better control than did full-cone nozzle no. 4.

9) Control with full-cone nozzle no. 5 was much better than with flat fan nozzle no. 1 although deposits were not significantly different. The better leaf coverage with no. 5 than with no. 1 at 3 mph may account for the differences in control. Similar differences in coverage on berries might have been shown if the maximum and minimum values had been recorded separately.

Under the conditions of this test on narrow rows a boom fitted with full-cone nozzle no. 5 operated at 300 psi and 3 mph travel speed should give effective control of rot with 5.6 lb of 50% captan wettable powder in 90 gallons of water per acre of strawberries.

Further testing is required to determine the effectiveness of the above arrangement in wider rows and taller, denser foliage.

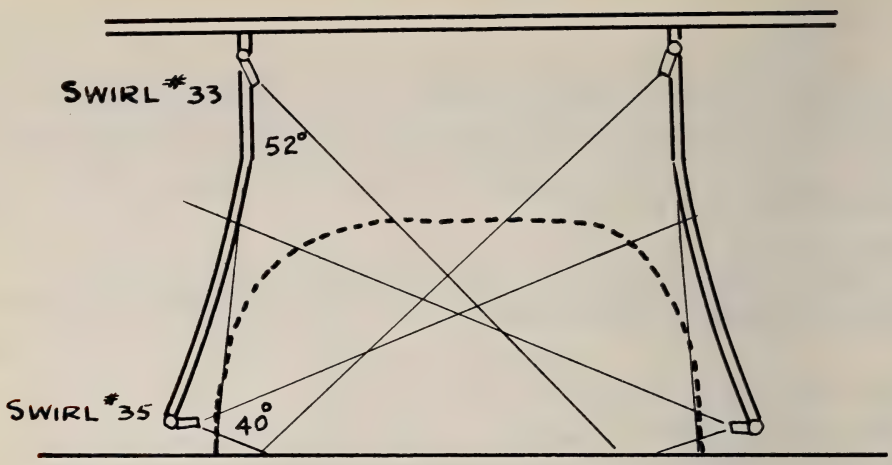

FIGURE 4 Nozzle arrangement and spray angles for full-cone nozzles (No. 5 in Table I).

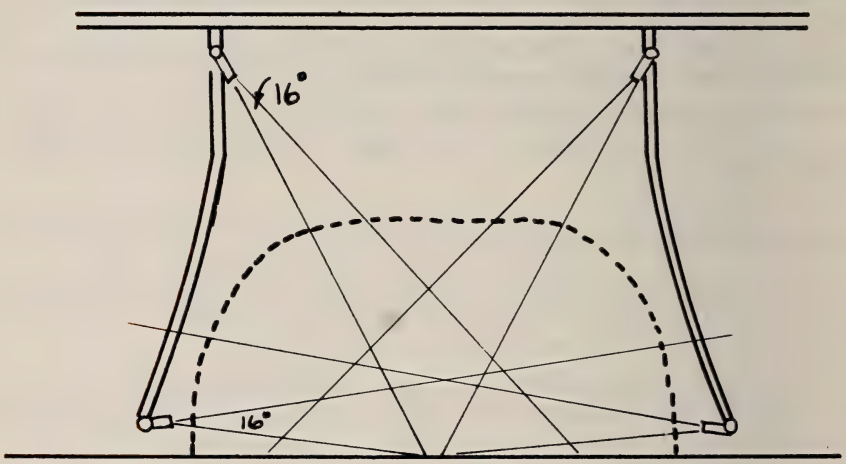

FIGURE 5 Nozzle arrangement and spray angles for full-cone nozzle (No. 4 in Table I).

Acknowledgements

The authors are indebted to Mr. Geoffrey Goodwin who provided the strawberry field and the sprayer, took weather records for timing of sprays, and applied the sprays throughout the season; and to Mr. G.P. Dougan for technical assistance.

Reference

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EFFICIENCY OF AN AIRBLAST SPRAYER IN APPLYING A FUNGICIDE TO CONTROL BOTRYTIS ROT IN STRAWBERRIES

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Abstract

Coverage of strawberries by an airblast sprayer applying 336 litres per hectare (30 gallons per acre) at 4.8 kilometres per hour (3 miles per hour) covering a swath of seven rows, which varied in width from 61 to 91 cm (24″ to 36″), was poor and highly variable. On the fruits and calyces coverage improved as row width decreased from 91 cm to 61 cm. Coverage was low in row one, near the sprayer, and maximum in rows two and three. Rot inoculum was so high that no differences in disease level were detectable despite large differences in coverage and deposit.

* * * * * *

Introduction

In a previous paper (Fisher and Hikichi, 1973) spray coverage, chemical deposit, and botrytis rot control were reported for a hydraulic boom sprayer with drop arms. Though hydraulic boom sprayers are most commonly used for rot control in strawberries, some growers use airblast row-crop machines. In 1971, one such sprayer with air-shear nozzles provided effective control in 61 cm (24″) rows in one location, but gave poor control in 91 cm (36″) rows at another location (Fisher and Hikichi, unpublished). To determine factors responsible for the differences, field plots with rows of variable width were sprayed under a uniform set of conditions.

This paper reports on spray coverage on fruits, calyces and leaves of strawberries, degree of control achieved in experimental plots, and economic loss due to rot, in a season of high disease level.

Materials and Methods

The experiment consisted of three replicates of each of three row width-lane width combinations, as follows (Fig. 1): 91 cm row, 31 cm lane; 76 cm row, 46 cm lane; and 61 cm row, 61 cm lane. Rows were modified by removing plants along each side at the time of first spring growth; by fruiting time they had spread to the prescribed widths.

Sprayer

A Kinkelder "Royal" row-crop sprayer was used. It emitted spray from both sides and covered a swath of 7 rows (3 on each side and 1 beneath the sprayer) at a speed of 4.8 km/hour (3 mph) and applied 336 l/ha (30 gal/a). For the test, 6 rows were sprayed from both sides as the sprayer straddled row# 0 in one direction and# 7 on the return (Fig. 2). Atomization was achieved by air-shear nozzles in an airstream travelling 288 km/hr (180 mph).

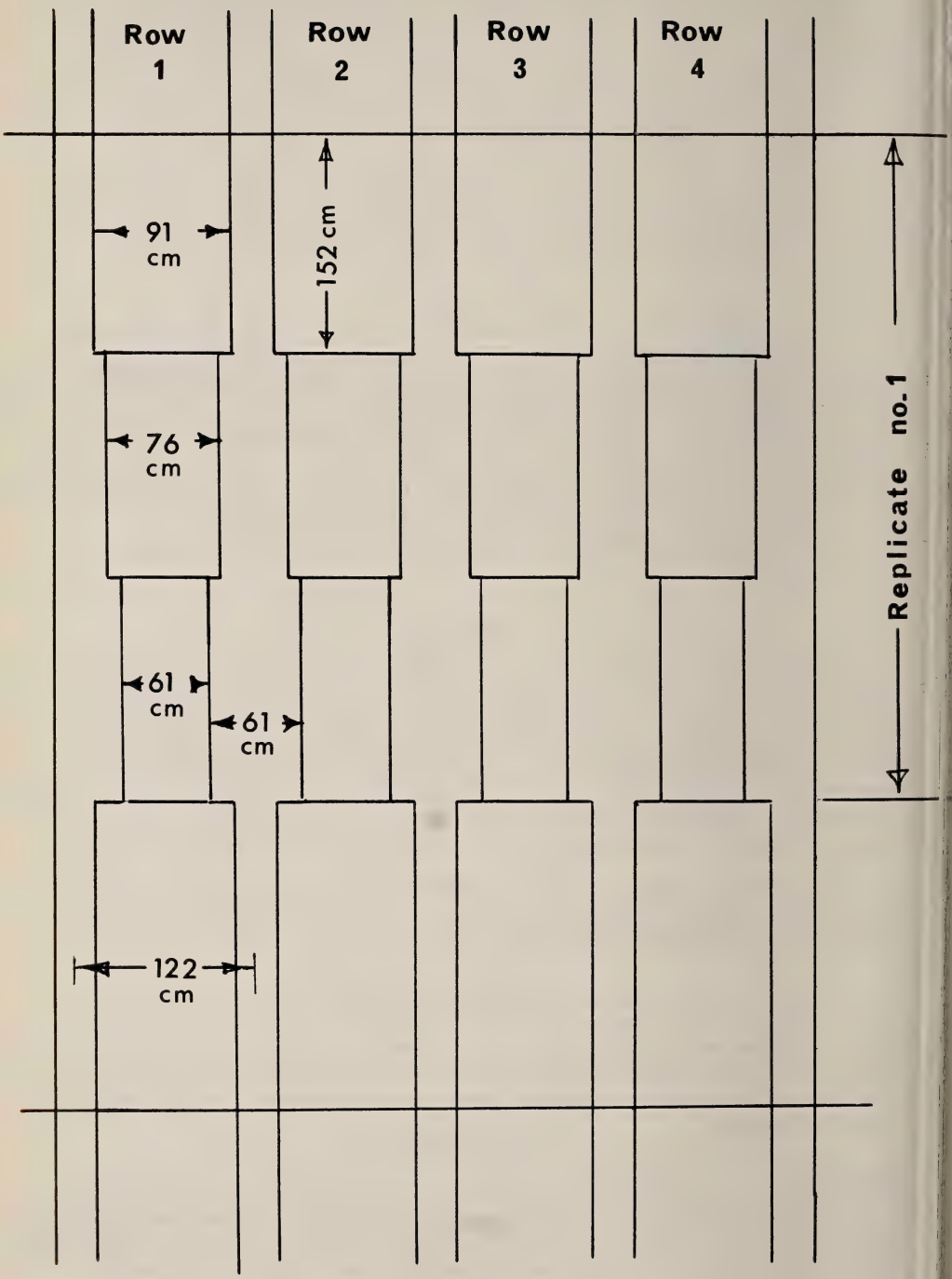

FIGURE 1 Schematic diagram of experimental plots, showing row and lane widths and replications.

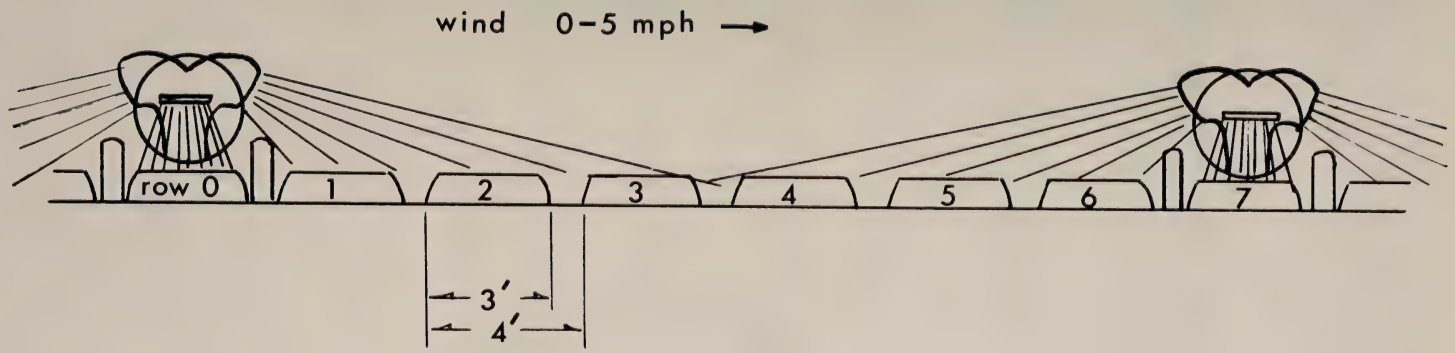

FIGURE 2 Schematic diagram of the rows, positions of the sprayer in applying the spray, the row widths and spacings, and the wind speed and direction.

Materials

All plots were sprayed with captan 50% wettable powder at 4.48 kg/ha (4 lb/a) in the regular schedule used by the grower: May 27, 31, June 8, 16, 25, 30, July 3, 10, 14. A fluorescent dye, Phosphor 2283, (excited at 2537 A) was added to the spray at 1.32 g/l (6 g/gal) on June 26 to assess coverage on leaves and fruits, and residues on paper targets.

Sampling of Leaves and Fruits

Immediately after the spray had dried, twenty leaflets were picked from the middle inside foliage of each plot. Each leaflet was examined under ultraviolet light (2537 A) with a stereoscopic microscope, and a rating was given for coverage on the lower surface according to the method of Fisher and Hikichi (1971).

Twenty-five fruits, about 1 cm in diameter, were picked from the middle of each plot and examined similarly. Each fruit was rotated and two ratings recorded: maximum and minimum. Maximum and minimum ratings were recorded similarly for the calyces (Fig. 3).

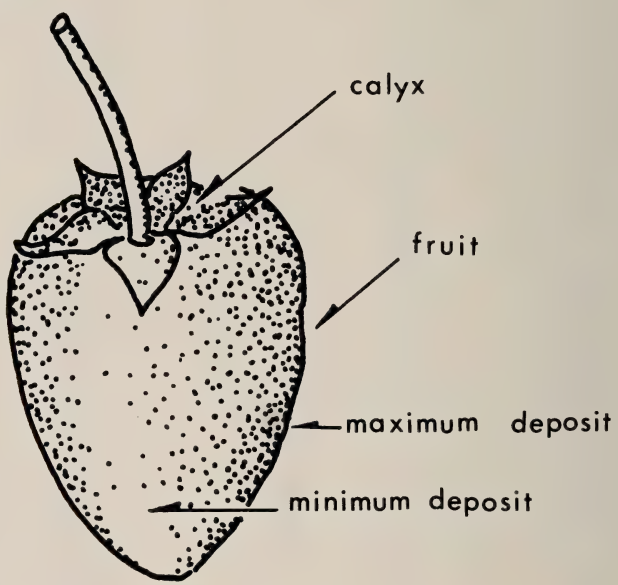

FIGURE 3 Diagram of a berry showing the fruit, the calyx, and the distribution of deposits around the circumference.

Sampling of Residues

Strips of green desk blotter, 11 cm x 4 cm (4 1/2″ x 1 1/2″) lightly impregnated with paraffin wax were formed into cylinders and placed over pieces of 3 cm dowel fastened to 40 cm x .63 cm (16″ x 1/4″) iron stakes. Two of these targets were placed in each plot, 15 cm — 20 cm (6″ — 8″) above the ground and within the berry plants; the axis of the cylindrical target was horizontal and parallel to the row. Each strip was fastened to the door of a Turner model 111 fluorometer and its fluorescence recorded for 7 positions (each 1.27 cm^2) by using the 30x incident light setting and 1% transmission of fluorescent light.

Rot Samples

On June 26, after 5 regular captan sprays had been applied, 100 green berries were examined *in situ* and the percentage rot was recorded. All ripe berries were picked from the plots at regular picking times (June 26, July 4, 11, 17, and 24). They were weighed and counted and the proportions of sound and rotted fruit were recorded.

Calculation of Yields and Loses

Gross yields, and net yields based on an average rot value were calculated for a row spacing of 48″ and for a constant width of lane between rows of different width.

Results and Conclusions

Spray Coverage of Leaves

Coverage on the lower surfaces of leaves was generally poor; it was lowest in row one, nearest to the air outlet of the sprayer, and higher in rows 3 and 4 where the spray streams overlapped (Table I & Fig. 2). The lower value in row 4 than in row 3 was probably due to the opposing west wind at the time of application, which reduced the driving force of the sprayer airstream. No marked differences in coverage occurred among the different row widths. The number of poor ratings (zero to one) was very high in row one and decreased to row 3.

TABLE I. Average visual assessment of dye deposit on the under surfaces of leaflets of strawberry (20 leaflets per plot, x 3 replicates, x 4 rows). Rating based on a range 1-10 (Fisher and Hikichi, 1971).

Row width	Row 1	Row 2	Row 3	Row 4	Average ratings	Percentage of ratings of 1 or less
24″	2.0	4.0	4.4	3.4	3.4	38
30″	1.7	3.5	3.6	2.8	2.9	42
36″	2.0	4.1	3.3	3.2	3.1	36
Averages	1.9	3.9	3.8*	3.1		
% with rating of 1 or less	59	27	21	32		

*A rating between 4 and 7 is considered adequate.

Spray Coverage on Calyces and Fruits

Because the fruit and its calyx were always more heavily sprayed on one side (Fig. 3), separate ratings of coverage for maximum and minimum deposits were made for fruits (Table II) and calyces (Table III). Again deposits were lowest in row one near the sprayer, and highest in row three. Spray coverage on both fruits and calyces decreased as the row width increased.

Dye Deposits

Results with the paper targets generally agreed with those for the leaves. The 61 cm (24″) row had the highest deposit of dye and the least number of zero values (Table IV). Also the lowest deposit was found in Row 1 while deposits in Rows 2 and 3 were much higher. This pattern of coverage was also found with fruits and

calyces, confirming the uneven distribution of spray across the four rows. The deposits in the 76 cm (30″) row were less than in the 61 cm and 91 cm rows, rather than the expected intermediate values, as found in the visual deposits on fruits and calyces. A similar pattern was found on the under-surfaces of leaflets; the cause was not obvious.

TABLE II. Average visual assessments of dye deposits on strawberry fruits (25 fruits from each of 3 plots, x 3 replicates x 4 rows). Rating based on a range 1-10 (Fisher & Hikichi, 1971).

Row width	Average minimum coverage values					Percentage of ratings of 1 or less
	Row 1	Row 2	Row 3	Row 4	Average	
24″	0.90	1.40	1.50	1.10	1.22	16
30″	0.55	0.96	1.08	0.65	0.81	34
36″	0.48	0.45	1.15	0.48	0.64	48
Average	0.64	0.93	1.24	0.74	0.89	

width	Average maximum coverage values					Percentage of ratings of 1 or less
	Row 1	Row 2	Row 3	Row 4	Average	
24″	4.3	5.0	5.5	5.3	5.0	17
30″	4.3	4.6	5.1	3.8	4.5	22
36″	3.8	4.2	4.2	2.8	3.8	29
Average	4.1	4.7	4.9	4.0	4.4	

TABLE III. Average visual assessments of dye deposits on strawberry calyces (25 from each of 3 plots, x 3 replicates, x 4 rows). Rating based on a range 1-10 (Fisher and Hikichi, 1971).

Row width	Average minimum coverage values					Percentage of calyces with a zero rating
	Row 1	Row 2	Row 3	Row 4	Average	
24″	2.1	2.3	3.2	2.2	2.5	10
30″	1.3	1.7	2.2	1.8	1.8	19
36″	1.6	1.9	2.3	1.5	1.6	23
Averages	1.7	1.9	2.3	1.8	1.9	

Row width	Average maximum coverage values					Percentage of calyces with a rating of 1 or less
	Row 1	Row 2	Row 3	Row 4	Average	
24″	5.1	5.4	6.5	5.2	5.5	7
30″	4.2	5.2	5.7	4.6	4.9	12
36″	4.7	5.0	4.4	4.1	4.6	15
Averages	4.7	5.2	5.5	4.5	5.0	

TABLE IV. Total fluorescence values for dye deposits captured on paper cylinders placed within the berry rows.

Row width	Row 1	Row 2	Row 3	Row 4	Totals	No. of zero values*
24″	36	116	129	71	352	66
30″	22	55	44	48	169	92
36″	26	62	77	54	219	75
Row totals	84	233	250	173		

*From a total of 168 readings on 24 targets.

TABLE V. Yields of strawberries from plots of different widths, and losses due to botrytis rot.

Picking Date	Row width (in.)	Total no. of ripe berries harvested	Total weight of ripe berries harvested (grams)	No. of rotted berries	Percentage of yield rotted
June 26	24	(100 green berries 1 cm. in diameter examined *in situ* in each plot)		276/1200	23
	30			321/1200	27
	36			297/1200	25
June 26	24	208	2101	28	13.4
	30	154	1933	27	17.6
	36	176	2417	22	12.5
July 4	24	571	5901	56	9.8
	30	716	8817	113	15.8
	36	734	9878	88	12.0
July 11	24	1072	6980	48	4.5
	30	1397	9239	59	4.2
	36	1484	9998	76	5.1
July 17	24	1082	6282	218	20.1
	30	1354	7570	289	21.3
	36	1801	8967	353	25.1
July 24	24	301	1251	28	9.3
	30	364	1566	31	8.5
	36	478	2077	42	8.8
Total Yield ripe berries	24	3234	22,515	378	11.7
	30	3985	29,125	519	13.0
	36	4673	33,337	581	12.4
Total Yield ripe	all widths	11,892	84,977	1468	
No. green berries not harvested*	all widths	447		447	
Total ripe + green*	all widths	12,339		1915	15.5

* assuming that half of the berries that rotted while still green would ripen and then be included in subsequent pickings.

Rot Incidence

After the fifth spray application (June 25) it was apparent that botrytis rot was not being controlled. Examination of *green* berries *in situ* showed that 25% of them irrespective of row width, were already affected and would not be marketable. Assuming that half of the rotted green berries would ripen and be counted in subsequent samplings, the total loss due to rotted green and ripe berries was 15.5% (Table V). The incidence of rot in ripe berries varied widely during the season with a minimum of 4.2% on July 11 and a maximum of 25.1% six days later. The number and size of berries and the proportion of rotted berries decreased as the weather became drier. This seasonal variation indicates the hazard of recording incidence in a field based on a single observation time.

Calculation of Losses

Linear lengths of row per acre were calculated for the three row widths and multiplied by yield per metre of row (550 g= 1 box). An average 15.5% loss caused by botrytis rot produced *net* yields of marketable fruit, and monetary losses (at 25c per quart box) as follows:

61 cm (24″) rows = 6370 boxes/acre with $292/acre loss

76 cm (30″) rows = 8250 boxes/acre with $378/acre loss

91 cm (36″) rows = 9287 boxes/acre with $426/acre loss

Based on a constant 29.6 cm (12″) lane width, values would have been as follows:

61 cm (24″) rows = 8409 boxes/acre with $386/acre loss

76 cm (30″) rows = 9909 boxes/acre with $454/acre loss

91 cm (36″) rows = 9287 boxes/acre with $426/acre loss

The 91 cm (36″) row gave the highest yield because it contained the greatest number of plants per acre. However, when considered on the basis of a constant lane width, the 76 cm (30″) rows would have had the greatest yield per acre. The 61 cm (24″) rows were least productive. However, the increased coverage on fruits and calyces in the 61 cm (24″) rows, if coupled with a higher rate of captan or a more effective fungicide, might well have brought the marketable yield closer to that of the 76 cm (30″) rows.

The generally poor coverage was probably due to a number of factors: dense, deep foliage that was difficult to penetrate; sloping sides on wide rows that kept the airstream from entering under the leaves; narrow lanes that allowed no deflection from the ground to the undersides of leaves and fruit; and a non-uniform air pattern that was easily deformed by light winds.

Earlier spraying with a high rate of Captan might well have checked the *Botrytis* at its source in the dead leaves.

Acknowledgements

The authors thank G.P. Dougan for technical assistance and I.B. Ells, and A. Maitland for assistance in harvesting and recording the field data.

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TOXICITY OF DURSBAN®, GARDONA® AND SEVEN OTHER INSECTICIDES TO WHITE-PINE WEEVIL *PISSODES STROBI* (PECK) AND OTHER COMPONENTS OF THE FOREST ECOSYSTEM

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Abstract

Direct contact toxicity of nine insecticides, BHC, Dursban® (0,0-diethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate), Gardona® (2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate), lindane, methomyl, methoxychlor, phosphamidon, phoxim and Zectran® (4-dimethylamino-3,5-xylyl methylcarbamate) was evaluated against adults of the white-pine weevil, *Pissodes strobi* (Peck) in search of an insecticide alternative to methoxychlor. All insecticides tested were better than methoxychlor. Phoxim was the most effective followed by Dursban and Gardona. Dursban and Gardona were recommended for field evaluation as phoxim was not available commercially. Gardona appears more promising in field than Dursban and it is less toxic to fish, birds and mammals.

* * * * * * *

Introduction

The white-pine weevil, *Pissodes strobi* (Peck), is the most serious pest of eastern white pine, *Pinus strobus* L, plantations in North America especially in Ontario (Belyea and Sullivan 1956). The insecticides used for its control were DDT (Connola et al. 1955, Crosby 1958, Connola 1961, Connola and Smith 1964, Godwin and Reeks 1967) and lindane (Crosby 1958, Hastings and Risley 1962). Due to the adverse effects of highly persistent insecticides (DDT and lindane) the less persistent methoxychlor, has been used for the last few years in Ontario without much success, although it is registered for weevil control by federal registration authorities. A joint meeting of Forest Protection Section, Ontario Department of Lands and Forests[1], the Great Lakes Forest Research Center and the Chemical Control Research Institute (C.C.R.I.) was held at Sault Ste Marie in 1970, to plan the chemical-control strategy against white-pine weevil. It was decided that an evaluation of potential insecticides should be carried out against the weevil under laboratory conditions, so that the more effective insecticides could be tested in the field. This study describes the laboratory evaluation of the toxicities of Dursban® (0,0-diethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate), Gardona® (2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate) and seven other insecticides carried out against white-pine weevil adults.

Materials and Methods

(i) *White-pine weevil adults*

White pine and Scots pine, *P. sylvestris* L., shoots infested with larvae of the white-pine weevil were collected in the Sault Ste Marie area and in southern Ontario by the staff of Forest Insect and Disease Survey, Canadian Forestry Service, and Ontario Department of Lands and Forests[1]. The mass collections were received at C.C.R.I., in late July. The infested shoots were stored in specially designed wooden

[1]Ontario Department of Lands and Forests changed to Ontario Ministry of Natural Resources in 1971.

cages 2′ x 2′ x 2′, screened with 18 x 20 mesh metal screening to confine the emerged adults. The sides of the cages were covered with heavy brown paper in such a way that approximately 1 1/2″ space was left at the top for light and air circulation. This was done to prevent quick drying of the shoots and to attract the weevil adults to the top of the cages. The infested foliage was kept at room temperature and sufficient moisture in the shoots was maintained by periodic spraying of mist. The adult emergence commenced in the second week of August and continued up to the first week of September. The adults were transferred every morning from the cages to small plastic trays lined with paper towels and containing white pine needles and twigs as food. They were stored in the trays at 4° to 5°C until the second week of September and then transferred into 128 oz glass jars containing duff collected from the white pine plantation and pieces of small white pine branches. The weevils were stored in these jars at 2° to 4°C from the third week of September until used for the toxicological experiments during February and March. Only those adults which were crawling at room temperature and which had started feeding on the branches were used in the tests.

(ii) *Insecticides and their Formulations*

The following nine insecticides were used in the investigation: BHC EC 10%, Dursban EC 48%, Gardona Technical 99%, lindane 99%, methomyl technical 99%, methoxychlor technical 99%, phosphamidon 90%, phoxim technical 73% and Zectran® (4-dimethylamino-3,5-xylyl methylcarbamate) old process technical 93.3% and new process technical 92%. BHC, lindane and methoxychlor were used for developing the toxicological data and as standards for comparing the efficacy of the new compounds. The technical grade insecticides or concentrates were diluted with dyed Velsicol AR 60 to the final concentration in most cases (Tables I and II). When technical grade or concentrate was not soluble in the Velsicol AR 60, the insecticides were first diluted with a mixture containing xylene 40%, acetone 30%, AR 60 20% and Tween-80 10%, and then diluted with AR 60. DuPont oil red was used as a tracer dye.

(iii) Insecticide Treatment

The spraying procedure was similar to that described by Nigam (1970). A modified Potter's tower was calibrated to deliver volumes of dyed insecticide solutions resulting in deposits equivalent to 0.1, 0.2, 0.4, 0.6, 0.8 and 1 gallon per acre. The calibration of the tower was carried out in time units by using a micro-syringe for the standard deposit on the required surface area (9 cm No. 1 Whatman filter paper circles). The deposits of insecticides were determined by the colorimetric method as described by Rayner (1956). Thirty adults per dosage in replicate groups of 10 were sprayed to determine contact toxicity. The spray was applied directly onto $C0_2$ anaesthetized adults placed on the Whatman filter paper circles. The deposit of active ingredient (AI) calculated in $\mu g/cm^2$ was used for the probit analysis. Two types of controls were used in the preliminary studies, i.e. controls treated with dyed solvent at the rate of 0.1 to 1 gallon per acre and controls without solvent treatment. There was no apparent effect of the solvent on the control mortality, so controls without solvent treatment were used in the final studies.

TABLE I. Toxicity of Insecticides to Adult *Pissodes strobi* (Peck) at 24 Hours after Treatment

Insecticide	AI Conc. (%)	Slope	LD_{50} $\mu g/cm^2$	Fiducial Limits	Relative Potency	Toxicity Index	LD_{95} $\mu g/cm^2$	Fiducial Limits	Relative Potency
Phoxim	1%	5.80	0.57	0.51- 0.63	3.77	377	1.10	0.95- 1.35	9.39
Dursban	2%	4.59	.78	.67- .88	2.76	276	1.77	1.50- 2.26	5.84
Gardona	2%	2.89	.79	.63- .96	2.72	272	2.95	2.18- 4.93	3.50
Zectran (new)*	2%	3.28	.92	.78- 1.07	2.34	234	2.92	2.26- 4.34	3.54
Methomyl	4%	1.82	1.35	1.04- 1.88	1.59	159	10.79	5.59-43.63	.96
Phosphamidon	4%	3.34	1.40	1.20- 1.64	1.54	154	4.34	3.25- 6.98	2.38
B.H.C.	5%	2.90	1.42	0.73- 2.23	1.51	151	5.24	2.94-94.25	1.97
Zectran (old)*	4%	1.97	1.88		1.14	114	12.85		.80
Lindane	5%	2.42	2.15	1.73- 2.63	1.00	100	10.33	6.84-22.53	1.00
Methoxychlor	10%	1.77	9.81	7.59-14.61	.22	22	83.55	39.21-489.0	.12

*Zectran prepared from old and new process.

TABLE II. Toxicity of Insecticides to Adult *Pissodes strobi* (Peck) at 72 Hours after Treatment

Insecticide	AI Conc. (%)	Slope	LD_{50} $\mu g/cm^2$	Fiducial Limits	Relative Potency	Toxicity Index	LD_{95} $\mu g/cm^2$	Fiducial Limits	Relative Potency
Phoxim	1%	6.57	0.44	0.39-0.48	1.63	163	0.78	0.68- 0.96	2.46
Dursban	2%	5.34	.48	.42- .55	1.50	150	.98	.83- 1.31	1.96
Gardona	2%	3.23	.54		1.33	133	1.76		1.09
Lindane	5%	3.89	.72	.41- .91	1.00	100	1.92	1.53- 3.36	1.00
Methomyl	4%	2.65	.73	.58- .88	0.99	99	3.03	2.23- 4.94	0.63
Zectran (new)*	2%	3.31	.74	.62- .86	.97	97	2.32	1.83- 3.31	.83
Zectran (old)*	4%	3.34	.84		.86	86	2.62		.73
B.H.C.	5%	3.98	.86		.84	84	2.24		.86
Phosphamidon	4%	3.53	1.16	1.00-1.34	.62	62	3.38	2.65- 4.93	.57
Methoxychlor	10%	2.34	4.39	3.39-5.36	.16	16	22.11	15.36-42.58	.09

*Zectran prepared from old and new process.

(iv) *Observations and Analysis of Data*

The adults were held at 21°C and 55-60% R.H. after treatment and provided with fresh white pine twigs. Mortality counts were made at 24, 48 and 72 hours after treatment and corrected for control mortality according to Abbott's formula (1925). The range of control mortality was 0-10%. Probit analysis of the data was carried out according to Finney (1964)[2],[3]. The relative potencies of the insecticides were calculated according to Finney (1964) and toxicity index according to Sun (1950) using lindane as the standard insecticide.

Results and Discussion

The LD_{50} and LD_{95} values in $\mu g/cm^2$ of active ingredient, potency relative to lindane, slope (b values) and toxicity index for 24 and 72 hours after treatment are presented in Tables I and II respectively. The insecticides are arranged in descending order of toxicity on the basis of LD_{50} values for each period of observation. The relative potencies are given at both LD_{50} and LD_{95} level because regression lines were not parallel. Fiducial limits of Zectran (old) could not be obtained due to very high mortality in most of the dosages at the tested concentration. In case of Gardona fiducial limits were obtained for 24 hours, but by 72 hours cumulative mortality was very high and fiducial limits could not be obtained.

The toxicity at the LD_{50} level increased for all the insecticides with increasing time after treatment, i.e. from 24-72 hours. However, this increase was not significant. At the LD_{95} level also, toxicity increased with time in all cases. The increase was appreciable in Gardona, methomyl, BHC, Zectran (old), lindane and methoxychlor. The slopes of the probit regression lines for each insecticide were not the same for the different periods of observations. Similarly slopes were not the same when different insecticides were compared at the same period of observations. Therefore the lines were neither parallel in the same insecticide for different periods of observation nor in different insecticide for the same period of observation, when analysed for the single line probit analysis.

Phoxim was the best as a contact insecticide followed by Dursban and Gardona at the LD_{50} and LD_{95} level at both periods of observations. Methoxychlor was the least toxic. The LD_{95} value of lindane was five times less at 72 hours than the 24 hour value. Lindane and methoxychlor are relatively slow acting as compared to other insecticides.

Phoxim is much less toxic to mammals than other insecticides tested (Kenaga and Allison 1969). This insecticide is still in the experimental stage and is not available commercially, so it can not be recommended for field evaluation at present. Dursban and Gardona are recommended for field evaluation as they are the next most active and are commercially available. Their effect on the other components of the forest ecosystem was compared with lindane and methoxychlor. They are relatively safer to fish than methoxychlor and lindane. The 24 hour LC_{50} for Dursban, Gardona, lindane and methoxychlor to rainbow trout are 0.05, 0.81, 0.04 and 0.02 ppm respectively (Udall 1963, Shell 1968, CDA 1969, Macek et al. 1969). The acute oral LD_{50} to white rat of Dursban, Gardona, lindane and methoxychlor are 97-276, 4000-5000, 76-200 and 5000-7000 mg/kg respectively (Kenaga & Allison 1969). The acute oral LD_{50} to mallard ducks of Dursban,

[2]Program No. S103, Statistical Research Service, CDA.

[3]Computer service, Univac 1108, provided by Biometric and Computer Division, Department of the Environment.

Gardona, lindane and methoxychlor are 70-80, >>2000, >2000 and >2000 mg/kg respectively (Tucker and Crabtree 1970). In the field studies carried out by C.C.R.I. against white-pine weevil, Gardona appears to be better than Dursban and it is less toxic to fish, mammals and birds. It was also found very effective against sawflies (Nigam 1968). It may prove a good insecticide for the control of white-pine weevil and appears to be more acceptable from the conservationist point of view.

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THE ARTHROPOD FAUNA IN UNSPRAYED APPLE ORCHARDS IN ONTARIO I. MAJOR PEST SPECIES

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Abstract

In unsprayed apple orchards in Ontario, the codling moth, *Laspeyresia pomonella* (L.), the apple maggot, *Rhagoletis pomonella* (Walsh), and the plum curculio, *Conotrachelus nenuphar* (Herbst.), were the most important pests. These insects were also of prime economic importance in commercial orchards. Several other species of Lepidoptera appeared to have the potential to become major pests under Ontario conditions.

Introduction

During the period 1968-1972 a survey was conducted in unsprayed and semi-abandoned apple orchards in southern Ontario to determine the insect and other arthropod species present. It was hoped that the information obtained might indicate those species that could assume pest status in commercial orchards where insecticide use was restricted in integrated control programs. In this paper the occurrence and relative importance of species attacking primarily the fruit and foliage are discussed.

Materials and Methods

The orchards in which these studies were carried out have been previously described (Hagley, 1970). In 1972 one orchard at Vineland and one at Meaford were regularly sampled, although collections were occasionally made at Bowmanville, Simcoe and Fonthill. Fruit and leaf damage was assessed by visual examination of fruit and leaf clusters, non-fruiting spurs and fruit samples taken at random throughout the growing season. Fruit damage was also assessed at harvest in some commercial orchards in the same areas. All arthropods collected were recorded and immature forms were reared to maturity where necessary for identification. Specific determinations were made by specialists at the Entomology Research Institute, Ottawa. Mrs. A. Bensink, MacDonald College, Quebec, determined the snail species.

Results

Insects Attacking Primarily the Fruit:

In all areas the major pest species were the codling moth, *Laspeyresia pomonella* (L.), the apple maggot, *Rhagoletis pomonella* (Walsh), and the plum curculio, *Conotrachelus nenuphar* (Herbst.) (Table 1). Although the average seasonal infestation due to the maggot was lower than that due to the codling moth, maximum infestation in localized areas due to the former was often higher. In some orchards total fruit damage from these two pests was 100%. *C. nenuphar* damage was widespread, but with the exception of 1969 the degree of fruit infestation observed was comparatively low. In 1969 all the fruit on individual trees in some orchards had one or more curculio feeding and/or oviposition punctures. Oatman *et*

al. (1966) and Glass and Lienk (1971) in similar studies reported extensive fruit damage caused by these species in Wisconsin and New York respectively. In the latter area the red-banded leafroller, *Argyrotaenia velutinana* (Walker), was also regarded as a major pest.

In the test orchards damage to fruit and foliage was caused by several species of Lepidoptera. *A. velutinana, Archips argyrospilus* (Wlkr.), *Choristoneura rosaceana* Harris, *Grapholitha prunivora* (Walsh), and *Spilonota ocellana* (D & S), were present in low numbers in most orchards throughout the study period and fruit damage due to these pests seldom exceeded 2-3%. In 1972, however, *C. rosaceana* was more prevalent than in other years and damage to fruit by this insect early in the season was as high as 4% in some orchards. In 1971 more than 50% of the non-fruiting spurs in a 3-acre block of trees were damaged by *S. ocellana.* Although the effect of the latter infestation on the tree was not assessed, damage to the fruit was only 4%. Damage due to this insect in 1972 was common in both unsprayed and commercial orchards, but did not exceed 6%. Larvae of *Archips semiferanus* Wlk., *Agryrotaenia quadrifasciana* Fern., *Choristoneura fractivittana* Clemens, *Hedia variegana* Hbn., *H. chionosema* Zell., *Pandemis canadana* Kft., *P. limitata* Rob., *P. lamprosana* Rob., *Pseudexentera mali* Freeman, *Sparganothis sulfureana* Clemens, *Amphipyra pyramidoides* (Guenee), *Lithophane* spp., *Palaeacrita vernata* (Peck) and *Dichomeris ligulella* Hbn. were also recovered. In a few orchards almost complete defoliation of trees resulted from feeding by the last two species mentioned.

The tarnished plant bug, *Lygus lineolaris* (P de B), and the pentatomid *Acrosternum hilare* Say, were the most common plant bug species observed. The apple red bugs, *Lygidea mendax* Reuter, and *Heterocordylus malinus* Reuter, were occasionally present. Damage due to these and other species was generally less than 1% although in 1972 it was just over 5% (Table 1). In 1972 the mullein bug, *Campylomma verbasci* (Mey.), also occurred in several orchards but fruit damage seldom exceeded 1-2%. However, in some commercial orchards and particularly on the cv. Red Delicious damage approached 100%.

Fruit damage due to the apple seed chalcid, *Torymus varians* (Walker), and the rose chafer, *Macrodactylus subspinosus* (F.), was rarely observed.

TABLE 1. Per cent insect damage to apple fruit in unsprayed orchards in southern Ontario.

Year	Codling Moth	Apple Maggot	Plum Curculio	Green Fruitworms	Leafrollers	Plant Bugs	Aphids
1968	41.8[a](58.1)[b]	25.5(93.5)	15.6(54.8)	10.7[a](19.1)[c]	—	0.6(14.3)	1.8(3.2)
1969	15.9(48.2)	10.8(72.2)	21.8(84.5)	6.6(18.0)	1.4(14.3)	0.8(4.0)	0.8(4.2)
1970	20.6(75.3)	10.6(96.7)	9.9(32.4)	2.9(12.4)	0.8(3.8)	0.9(3.1)	0.4(5.4)
1971	23.4(42.4)	11.9(64.6)	12.7(30.9)	3.0(10.0)	2.4(6.5)	1.6(4.9)	1.7(4.5)
1972	26.3	40.7	2.5	6.1	3.4	5.4	0.2

[a]Figures in the first column represent average seasonal damage

[b]Figures in brackets represent maximum observed damage

[c]Total damage caused by leafrollers and fruitworms in 1968

Insects Attacking Primarily the Foliage:

The green apple aphid, *Aphis pomi* (DeG), was the most widespread species of aphid. The rosy aphid, *Dysaphis plantaginea* (Passerini) was frequently found on foliage early in the summer and occasionally caused economic fruit injury, particularly on the cv. Courtland. Low populations of the grain aphid, *Rhopalosiphum fitchii* (Sanderson), and the woolly aphid, *Eriosoma lanigerum* (Hausm.), were also observed in some orchards. The latter species appeared to be more numerous in commercial orchards during the latter part of this study than it was initially. Infestations of *A. pomi* on young, non-bearing trees caused considerable foliage damage and probably adversely affected photosynthesis and growth.

In most orchards the tentiform leafminer, *Lithocolletis blancardella* Fab., and the serpentine leafminer, *Nepticula pomivorella* Pack., were present. In 1970 *L. blancardella* caused severe damage to leaves throughout the apple growing areas of southern Ontario. In some orchards over 90% of the total number of leaves on individual trees were affected, and as many as 11 mines were observed in a single leaf. *N. pomivorella* was not as abundant but occasionally caused some fruit damage in unsprayed orchards. The eastern tent caterpillar, *Malacosoma americanum* (F.), was periodically observed in nests on the upper limbs of trees but only occasionally was the damage to foliage severe. In some areas the fall webworm, *Hyphantria cunea* (Drury), also caused extensive foliage damage. The apple skeletonizer, *Anthophila pariana* (Clerck), the pistol casebearer, *Coleophora malivorella* Riley, and the cigar casebearer, *C. serratella* (L.), were frequently observed though only in low numbers. *C. malivorella* caused some fruit damage in a few areas, particularly on the cv. McIntosh. Lord (1972) reported that the latter two species, as well as *L. blancardella,* caused considerable foliage damage in unsprayed orchards in Nova Scotia.

Several species of Homoptera occurred in large numbers on the foliage in a few orchards. The white apple leafhopper, *Typhlocyba pomaria* McA., was probably the predominant species and in a few orchards caused severe mottling of the foliage. *Gyponana* sp. and *Aphrophora* sp. were also commonly observed. The buffalo treehopper, *Stictocephala bubalis* (Fab.), was generally present in low numbers and occasionally damaged the bark on young trees.

Scale insects were present in very low numbers on individual trees in most orchards. The oystershell, (*Lepidosaphes ulmi* (L.), and San José, *Quadraspidiotus perniciosus* (Comstock), scales were more frequently observed than the European fruit scale, (*Q. ostreaeformis* (Curtis)).

In the more northern apple growing regions, however, the latter species predominated. The European scale, *Lecanium* sp., was also observed, and fruit and leaf discolouration often occurred due to the development of a fungus on its honeydew.

The European red mite, *Panonychus ulmi* (Koch), was usually absent from orchards that had not received an insecticide or miticide spray for 3-4 yr. Occasionally, however, a few individuals of this species, and the two-spotted spider mite, *Tetranychus urticae* Koch, were observed on foliage. In general, large populations of the apple rust mite, *Aculus schlechtendali* (Nalepa), and the brown mite, *Bryobia rubrioculus* (Scheuten) were observed (cf. Lord, 1972). In some years rust mite damage was severe and resulted in mottling and yellowing of the leaves. The pear rust mite, *Epitrimerus pyri* (Nalepa), and the pear leaf blister mite, *Eriophyes pyri* (Pag.), were observed in several orchards, but were generally present

in lower numbers. The rust mites, however, probably provided a food source for the predacious species which were abundant in these orchards (c.f. Herbert and Sanford, 1969).

In one orchard at Meaford the snail, *Cepaea nemoralis* (L.), was frequently observed on the foliage and may have caused occasional fruit damage.

Discussion

The major pest species (*L. pomonella, R. pomonella,* and *C. nenuphar*) in unsprayed orchards were also of prime importance in commercial orchards in southern Ontario. This suggests that the biotic agents present do not greatly influence fluctuations in the numbers of these pests, and until other control methods are developed, the use of chemicals, perhaps under more restricted conditions in an integrated program, will have to be continued. It must be pointed out, however, that changes in pesticide usage which will occur in an integrated program will undoubtedly affect the status of some species and relatively minor or hitherto unrecognized pests may assume major economic importance. It is also apparent that several leafrollers could become pests in Ontario apple orchards. *A. velutinana* which is often troublesome in commercial orchards has been previously reported causing economic damage, (Hall, 1929; Hikichi, 1963); and *A. argyrospilus* an important apple pest prior to the advent of DDT (Hikichi, 1963), may again become a pest problem. In addition, *G. prunivora, S. ocellana, C. rosaceana, C. fractivittana, D. ligulella, Lithophane* spp. and *A. pyrimadoides* appear to have the potential to become economic pests. Chapman and Lienk (1971) also point out that about 24 tortricid species recorded as occasional feeders on apple in New York must be regarded as potential pests. Among these, *P. mali, A. quadrifasciana, P. lamprosana, A. semiferanus, H. chionosema,* and *S. sulfureana* could become important pests under Ontario orchard conditions.

The relative importance of indirect pests is difficult to establish in the absence of relevant economic threshold data. It is, however, apparent that the severe foliage damage caused by large infestations of *Lithocolletis* sp., *T. pomaria, A. schlectendali,* and *A. pomi,* particularly on young non-bearing trees, must affect tree physiology and fruit production. Establishment of dwarf, high density plantings in Ontario makes it imperative that studies of the effects of these insects on their host plant be undertaken.

The scale insects, especially *Q. perniciosus* and *Q. ostraeformis,* are also potential economic pests, particularly if spray volumes are reduced.

Populations of *P. ulmi* and *T. urticae* were effectively controlled by predacious mite species in unsprayed orchards. In orchards under a reduced spray program, however, *P. ulmi* might assume pest status before the numbers of predators increased sufficiently to hold its populations at economically low levels.

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FIELD TRIALS TO CONTROL SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (CLEM.), THROUGH AERIAL APPLICATION OF *BACILLUS THURINGIENSIS*[1]

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Abstract

Three 160-acre spruce-fir plots were sprayed with aqueous suspensions of commercial preparations of *Bacillus thuringiensis* Berliner and various adjuvants formulated to effect control of spruce budworm on both balsam fir and white spruce. The rates of application were 3.6 and 4.0 Billion International Units per U.S. gallon per acre. Budworm mortality due to treatments was estimated at 96 to 99% on balsam fir and 80 to 86% on white spruce 33 days after spraying. The influence of environmental factors in conjunction with treatments is discussed.

* * * * * * *

[1]Contribution No. 247.

Introduction

Laboratory testing of *Bacillus thuringiensis* demonstrated pathogenicity to the spruce budworm provided the larvae ingested even minute quantities of the spores and crystals (Yamvrias and Angus, 1970). The objective of these field trials was to determine if relatively small quantities could be dispersed over the host trees in such a manner as to kill or otherwise render the budworm incapable of defoliating to the extent leading to host mortality.

Previous field testing on individual white spruce using a mistblower showed that a high percentage of larval mortality was possible when treatment was delayed until the current shoots were fully opened (Tripp, 1971). The budworms, however, have usually reached the fifth and sixth instars by that time and the amount of foliage saved is normally not sufficient to provide the necessary protection. To provide foliage protection during the current year, treatment during or before the fourth stadium is normally required but the secluded feeding behaviour at that time is a

barrier to deposition of *B.t.* at the feeding sites. A solution to this problem requires the use of particular adjuvants and techniques of application to effect a more complete coverage with relatively small quantities of spray.

The field trials during 1972 employed the use of a Grumman AgCat aircraft with four Micronair AU 3000 units capable of delivering droplets of 50 micron diameter or less, thereby ensuring adequate coverage with one gallon spray per acre. In an attempt to effect early larval mortality on both balsam fir and white spruce, selected adjuvants were included to enhance penetration and residual qualities.

The Experimental Area

The site selected was a severely infested spruce-fir stand located about 25 miles west of Chapleau, Ont., along Highway 101. Three adjacent plots of 160 acres each were measured off and later marked at the corners with large red helium-filled balloons. Each plot measured 3/4 of a mile long by 1/3 mile wide. One check area was selected about one mile to the west and a second adjacent to the treated plots to the east.

Trails were cut to establish two sample stations near the central part of each plot. Sample trees were selected at each sample station and along the trails.

A weather station was set up a few feet above ground level near the central point of the experimental area. Continuous records of temperature, humidity, rainfall, and hours of sunlight were obtained from a week prior to spraying to the end of the sampling period.

Formulations

Two commercial *B.t.* products, namely Dipel® wettable powder supplied by Abbott Chemical Co., and Thuricide® liquid concentrate supplied by International Minerals Corp., were used (Table I). No attempt was made to compare the effectiveness of these products but the International Units per acre were kept more or less the same so as to evaluate the various adjuvants. Previous experience gained through ground spraying with a mistblower had indicated that 1/2 lb. of Dipel® in one U.S. gallon of spray per acre would be adequate. The toxicity rating of the Dipel® is 3.6 B.I.U. per half lb., whereas one quart of Thuricide® is rated at 4.0 B.I.U. The 10% difference was not considered sufficiently great to warrant further adjustment.

TABLE I. Formulations per U.S. gallon of aqueous spray per acre.

Plot	B.t.	Adjuvants
1	1 quart Thuricide HPC (4 B.I.U.)	1 pint molasses (12.5%) 5.9 oz. Nu-film (4.6%)
2	1/2 lb. Dipel WP (3.6 B.I.U.)	3.2 oz. sunlight protectant (2.5%) 1.5 oz. Bio-film (1.1%)
3	1/2 lb. Dipel WP (3.6 B.I.U.)	1 quart C.I.B. (25.0%)

The objective of the adjuvants was to provide a combination of wetting, sticking, and protection from ultra-violet radiation. Cargill Insecticide Base (C.I.B.) is a proprietary formulation which is essentially molasses with small quantities of an

emulsifier, preservative, and anti-oxidant. It is designed to improve spreading and sticking characteristics and because of its dark colour should provide some protection to the spores from sunlight. Also, it serves well as a marker on the spray-deposit cards. Because of an insufficient supply, however, an animal-feed grade of molasses diluted to one pint per gallon was substituted in the formulation for plot 1. Nu-film® (Millar Chemical and Fertilizer Corp.) was added to the molasses in plot 1 to provide an extra measure of sticking and anti-evaporant characteristics. Bio-film® (Colloidal Products Corp.) which has very good spreading characteristics even at low concentrations was added to the formulation for plot 2 in an attempt to achieve better coverage on white spruce. In this formulation a sunlight protectant supplied by International Minerals Corporation also served as the marker on the spray-deposit cards.

The Spray Operation

Budworm development was checked periodically prior to spraying to ascertain the best time to apply treatments. It had been decided to spray when fourth instar budworms were first recorded or when balsam fir buds were sufficiently open to allow the spray to penetrate between the needles. Based on the first appearance of second instar larvae this was anticipated around June 5, but very high temperatures during the latter half of May advanced development so rapidly that by May 26th samples revealed 8% second, 44% third, and 48% fourth instars. The spray was applied on the morning of May 28th. Spraying began on plot 3 shortly before 7 a.m. and was completed in about a half hour. Plot 2 was treated next commencing shortly before 8 a.m., and finally plot 1 was completed shortly after 9 a.m. During this period a light breeze held fairly steady at an estimated 5 m.p.h. causing a slight drift to the north. The temperature rose steadily from about 40°F at 7 a.m. to about 60°F at 9 a.m. with a drop in the relative humidity from almost 100% to near 50%. The higher temperatures and lower humidity prevailing during the spraying of plots 2 and 1 were far from ideal but it was highly desirable to treat all plots on the same day. An examination of the spray-deposit cards revealed good coverage for all plots with drop diameters ranging from 50 to 300 microns (av. 125).

Post-spray Weather

Two days following the spray (May 30) the experimental area was subjected to temperatures slightly below freezing (30°F) and a snow-fall of about 3 inches. The following morning the temperature dipped to a low of 27°F. Subsequent sampling revealed that virtually all of the current year's foliage on balsam fir and a high percentage on white spruce was destroyed. Budworm mortality, however, was less than expected. Eighteen-inch branch samples taken from the check area a month after the frost revealed an average of 4.75 living budworm on balsam fir and 9.0 on white spruce (Table IV).

Assessment

The assessment of these trials was based entirely on estimations of population reduction due to the treatments. Normally, an estimation of foliage protection is also made but this was impractical in view of the frost damage to current year's foliage. There would be a difference in the amount of old foliage consumed but reliable techniques for estimating current defoliation of old foliage have not been devised.

All counts of budworm were taken from eighteen-inch branch samples collected from the mid-crowns of the sample trees. Data were analysed by three methods. The first, utilized pre- and post-spray collections from the same trees; the second, employed the ratio of living and dead budworms; and the third, compared the number of living budworms between treated and untreated plots 10 days and 33 days after treatment.

The method based on pre- and post-spray samples from the same trees has the advantage of reducing error due to variation in population levels between trees. However, larval counts from pre-spray samples are more likely to be in error in that the young larvae are more difficult to detect. Also, a pre-spray collection is more difficult to procure because of limited time available prior to treatment. In this instance, time permitted sampling of only five balsam fir trees from the check plot and ten each from the three treated plots. The population reduction in treated plots was estimated at 98.7, 96.1, and 96.1% for the Thuricide-1, Dipel-2, and Dipel-3 plots, respectively, which when adjusted to remove natural mortality by Abbott's formula (Abbott, 1925) results in control estimates of 95.1, 85.2 and 83.2%, respectively (Table II).

TABLE II. Estimated control of the spruce budworm on balsam fir 9 days after aerial spraying of *Bacillus thuringiensis* on May 28 by comparison of pre- and post-spray population levels on the same trees.

Plots	Living budworm per 18-inch branch sample			
	Pre Spray May 27	Post Spray June 7	% Mortality	% Control
Unsprayed	50.2	13.2	73.7	—
1 (Thuricide)	47.2	0.6	98.7	95.1
2 (Dipel)	38.4	1.5	96.1	85.2
3 (Dipel)	35.8	1.4	96.1	83.2

Estimates of control based on the ratio of living to dead budworms is likely to under-estimate the effectiveness of treatments in that cadavers are less likely to be recovered than are living larvae. Nevertheless, the results using this method (Table III) are remarkably close to those obtained by utilizing pre- and post-spray counts of living larvae. The unsprayed plot showed an average of 0.8 dead larvae per eighteen-inch balsam branch which when compared with an average of 13.2 living larvae results in an estimated natural mortality of only 5.7%. The mortality in the sprayed plots was calculated to be 93.4, 85.0, and 84.4%, respectively for plots 1, 2, and 3, which, when adjusted to remove natural mortality, indicates control due to the treatments of 93.0, 84.1, and 83.5%.

A total of 229 cadavers from these samples was examined for the presence of *Bacillus;* 81% of those from the treated plots revealed vegetative growth, whereas all from the check area were negative for *Bacillus*. Although *Bacillus thuringiensis* cannot be positively identified by this method, the presence of *Bacillus* rods only in the cadavers from treated plots is good presumptive evidence that the budworms were indeed killed by the application.

TABLE III. Estimated control of the spruce budworm on balsam fir 9 days after aerial application of *Bacillus thuringiensis* by comparing number of living and dead larvae.

Plots	Budworm per 18-inch branch sample			
	Living	Dead	% Mortality	% Control
Unsprayed	13.2	0.8	5.7	—
1-Thuricide	0.6	8.5	93.4	93.0
2-Dipel	1.5	8.5	85.0	84.1
3-Dipel	1.4	7.6	84.4	83.5

Following this initial sampling, additional trees of balsam fir and white spruce were selected from each plot. These trees provided an increase in the number of samples and covered a larger area in each plot. The collections were taken at two periods, 10 and 33 days after spraying. The analysed data are presented in Table IV.

Since only post-spray counts of living larvae are available the data must be analysed by comparing the population levels between plots. This method makes the assumption that pre-spray population levels between plots were similar and that recorded differences are due to the treatments. When one considers the very high population levels prevailing throughout the area, the close proximity of the plots, and the more or less uniform composition and density of the trees, this assumption does not seem unreasonable. The percent controls measured on balsam fir 10 days after spraying were 96.4, 91.5, 93.0, respectively, for plots 1, 2, and 3. The balsam fir samples taken 33 days after spray revealed increases in percent control to 98.9, 95.8, and 95.8 for plots 1, 2, and 3.

TABLE IV. Estimated control of the spruce budworm by *Bacillus thuringiensis* treatments on balsam fir and white spruce by comparison with the population levels in an untreated area.

Plot	Tree species	Results					
		10 days after treatment			33 days after treatment		
		No. of samples	Means*	Percent control	No. of samples	Means*	Percent control
Untreated	Bf	20	14.05	—	20	4.75	—
	Ws	20	22.45	—	18	9.0	—
1 (Thuricide)	Bf	40	0.50 A	96.4	20	0.05 D	98.9
	Ws	28	7.43 C	66.9	20	1.75 E	80.6
2 (Dipel)	Bf	40	1.20 B	91.5	20	0.20 DF	95.8
	Ws	29	9.97 C	55.6	20	1.25 EF	86.1
3 (Dipel)	Bf	40	0.98 AB	93.0	20	0.20 D	95.8
	Ws	34	10.85 C	51.7	20	1.80 E	80.0

*Means followed by a letter in common are not significantly different at the 0.05 level of probability.

The increase in control between the two sample periods was even more evident on white spruce, but the extent of control considerably less. The percent controls on white spruce 10 days after spray were estimated at 66.9, 55.6, and 51.7, respectively, for plots 1, 2, and 3. These percentages increased to 80.6, 86.1, and 80.0, respectively, 33 days after spraying.

With one exception, the differences of means between treatments on balsam fir or on white spruce were not significant. The exception occurred between plots 1 and 2 on balsam fir 10 days after spraying. Again, with one exception, the control effected on balsam fir as compared to that on white spruce was significantly greater. This is not surprising in view of the more secluded feeding sites on white spruce. The exception occurred 33 days after spraying in plot 2 which is encouraging in that the spray used on this plot was specifically formulated to effect control on white spruce.

Discussion

These trials indicate that the *B.t.* formulations had a residual effect beyond a 10-day period and that a dosage of 4 B.I.U. per U.S. gallon per acre is sufficient to effect satisfactory budworm mortality. One of the elements which precludes a firm recommendation for the widespread aerial application of *B.t.* against spruce budworm is the incidence of frost shortly after the application. The resultant destruction of the current foliage would force surviving budworms to feed on old foliage which probably received a more thorough coverage of *B.t.* Since it is not possible to predict the outcome had frost not occurred it is necessary to repeat the trials.

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THE POSSIBLE USE OF VIRUSES IN THE CONTROL OF SPRUCE BUDWORM[1]

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Abstract

A nuclear polyhedrosis virus (NPV) and an entomopoxvirus (EPV) of the spruce budworm, *Choristoneura fumiferana* (Clemens), were propagated in the laboratory and sprayed from a helicopter on 8 small plots near Pembroke, Ontario, in 1971. The efficacy of the spray was evaluated by diagnosis of samples of larvae to determine the percentage infection, by population reduction studies, and by defoliation analyses. In the following year (1972) the plots were again sampled to assess the carry-over potential of the viruses from one generation to the next and encouraging results were obtained.

* * * * * *

Introduction

The objective of using a virus to control spruce budworm, *Choristoneura fumiferana* (Clemens), is the establishment of the virus in the insect population so

that it will persist from one year to the next and spread from the area of initial introduction. Hopefully, the virus reduces the insect population to such a level as to give foliage protection and prevent tree mortality. Successful use of viruses is exemplified by the control of two species of sawflies, *Diprion hercyniae* (Hartig), and *Neodiprion sertifer* (Geoffroy), using nuclear polyhedrosis viruses (Bird, 1961), and it is hoped that a similar approach will give control of the spruce budworm.

Several viruses have been isolated from the spruce budworm: a nuclear polyhedrosis virus (NPV) (Bergold, 1951), a cytoplasmic polyhedrosis virus (CPV) (Bird and Whalen, 1954), and a granulosis virus (GV) (Bergold, 1950). Recently, an entomopoxvirus (EPV) was isolated from the 2-year-cycle budworm, *C. biennis* Freeman, which occurs in British Columbia and this virus was found to infect *C. fumiferana* (Bird, Sanders and Burke, 1971). Laboratory tests showed that, although slow acting, the entomopoxvirus was much more infectious than the NPV. Ground spray trials of virus on spruce budworm using pressure sprayers have been conducted by Stairs and Bird (1962) who used NPV and GV. Further studies were conducted with NPV by Bird and McPhee (1970). They investigated different application times to determine at which stage of development budworm larvae were most susceptible to a virus application.

During 1971 and 1972, personnel of the Great Lakes Forest Research Centre and the Insect Pathology Research Institute collaborated in conducting studies on the dissemination of virus by helicopter using NPV and EPV against spruce budworm. The impact on the population was studied by a variety of methods. Staff of the Great Lakes Forest Research Centre undertook quantitative population reduction studies and made defoliation estimates, whereas staff of the Insect Pathology Research Institute determined the incidence of virus infection in larvae on the sprayed plots and control areas.

This paper reports the operational details of the spray trials and describes the impact of the viruses on the spruce budworm population.

Materials and Methods

Virus Production

Spruce budworm larvae were reared in 3/4 oz. plastic cream cups on artificial diet (McMorran, 1965) without the addition of formaldehyde (Vail *et al,* 1968). Larvae intended for EPV production were infected when in the second-instar and those for NPV production in the fifth-instar. They were reared at 75°F, 50-55% RH and with a 15 hour photoperiod. Heavily-infected living larvae were harvested, frozen, freeze-dried and ground to a fine powder in a Waring blender. Before field use the powder was put in suspension using a Kalish homogenizer. The larval equivalents (sixth-instar) were 1.3×10^8 inclusion bodies for the entomopoxvirus and 0.6×10^8 for the NPV. In 1970-71, 222,000 larvae were infected with EPV and 1,885 gm freeze-dried infected material obtained; the same number of larvae yielded 2,300 gm of NPV (Cunningham *et al,* 1972).

Application of virus in the field

In 1971 six 4.8-acre and two 6-acre plots were selected near Pembroke, Ontario. The six 4.8-acre plots containing white spruce and balsam fir were sprayed with EPV in an aqueous suspension with 2.5% (w/v) IMC sunlight protectant[1] added. The two 6-acre plots, which contained white s pruce only, were sprayed with NPV in an

[1]Manufactured by International Minerals and Chemical Corporation, 5401 Old Orchard Rd., Skokie, Illinois 60076.

aqueous suspension with no additives. Three plots were sprayed with EPV and one plot with NPV when larvae were mainly second-instar and the remaining three EPV and one NPV plot were sprayed when larvae were in the third- and fourth- instars. Virus concentrations, acreages and number of viral inclusion bodies per acre are given in Table I. The application rate on all plots was 3 U.S. gal./acre. A Hughes helicopter fitted with a boom and nozzle system was used for the spray application.

TABLE I

Plots sprayed in 1971 near Pembroke, Ontario[1]

Virus	Acreage	Conc. of freeze-dried material (gm/gal)	No. of viral inclusion bodies/acre
EPV	4.8	10	1.2×10^{11}
EPV	4.8	1.0	1.2×10^{10}
EPV	4.8	0.1	1.2×10^{9}
NPV	6.0	25	3×10^{11}

[1]These plots were duplicated in an early and a late application.

Evaluation of the Impact of the Viruses

The impact of the viruses on the spruce budworm population was evaluated by three methods in 1971 and 1972. These were microscopic diagnoses to determine a percentage infection figure, population reduction studies, and defoliation estimates.

1) *Microscopic diagnosis:* Random samples of 18″ branch tips were taken throughout the plots at weekly intervals from white spruce and balsam fir when both species were present. Samples were also taken from suitable control areas. All spruce budworm, living or dead, larvae or pupae, were removed from the foliage. Living larvae were dissected and squash preparations were made of the guts and portions of the fat tissue. Dead larvae were smeared without dissection or, if they were dessicated, they were ground up in a drop of water using a glass rod. The smears and squash preparations were examined under phase contrast for the presence of inclusion bodies of EPV, NPV or CPV. A percentage infection figure was obtained from combining data on living larvae and cadavers. When there were large numbers of pupae in the samples they were kept until adult emergence. If adults emerged they were considered healthy and only the dead pupae were examined microscopically.

2) *Population reduction studies:* The degree of population reduction due to the virus sprays was determined in both 1971 and 1972 by methods similar to those used to evaluate chemical control operations against spruce budworm in Ontario (Howse, Harnden and Sippell, 1972). Basically, densities of living budworm were determined in treated plots and untreated plots (controls), before and after treatment, or periodically through the larval and pupal stages of development. Abbott's formula (Abbott, 1925) was then used to calculate the effectiveness of the treatment by adjusting the percent mortality in the treated plots in relation to the percent mortality in the control plots.

3) *Defoliation estimates:* Estimates of the degree of damage or percent current defoliation were obtained by two methods. Treated and untreated (control) areas were examined by experienced observers from aircraft in late June or early July. Overall estimates of the degree of damage and obvious differences between treatments and controls were noted. These aerial observations were accompanied by

detailed examination and estimates of the degree of defoliation of branch samples collected from treated areas and control plots after budworm had ceased feeding.

Results

EPV plots

Examination of larvae from all the plots in the year of application revealed that the EPV suspension was contaminated with NPV and CPV. These viruses were found only in treated plots. The maximum percentage of infection from each virus during the season on each plot is given in Table II along with the percent population reduction figures. There was little protection afforded to the current foliage of either white spruce or balsam fir by the EPV sprays.

TABLE II

Percentages of virus infection and population reduction in EPV plots in 1971.

Concentration of freeze-dried material (gm/gal)	Time of spray	Tree species[1]	Percent virus infection[2] EPV	CPV	NPV	Percent population reduction due to treatment
10.0	Early	wS	38	7	10	40
		bF	9	0	1	0
	Late	wS	5	1	7	79
		bF	6	0	4	30
1.0	Early	wS	16	4	12	61
		bF	3	1	0	0
	Late	wS	2	0	1	57
		bF	2	0	0	48
0.1	Early	wS	12	0	2	25
		bF	1	0	0	0
	Late	wS	6	0	0	59
		bF	4	0	0	0
Control		wS	0	0	0	

[1]wS = white spruce
bF = balsam fir

[2]Total of living larvae and cadavers.

In the year following application, samples for microscopical diagnosis were taken from the early and late spray plots with the heaviest application. Very few infected larvae were found until late in the season when most of the larvae were in the sixth-instar and some had pupated. The maximum percentages of virus infection reached in 1972 are given in Table III along with maximum infection found in 1971. It can be seen that there was a marked decline in EPV infection and a considerable increase in NPV. There was some increase in CPV but as up to 3% of the control population was also infected with this virus it is difficult to evaluate its status. There was, however, no EPV or NPV in nearby controls. Marked population reductions and considerable foliage protection were recorded in the year following application and are shown in Table IV.

TABLE III

Percentages of virus infection in 1971 and 1972 in 2 EPV plots sprayed with 10 gm/gal in 1971.

Time of spray	Year of sample	Tree species	Percent virus infection EPV	NPV	CPV
Early	1971	wS	38	10	7
	1972	wS	5	19	5
Early	1971	bF	9	1	0
	1972	bF	0	7	2
Late	1971	wS	5	7	1
	1972	wS	0	20	4
Late	1971	bF	6	4	0
	1972	bF	0	17	10

TABLE IV

Population reduction and defoliation in 1972 in 2 plots sprayed with 10 gm/gal freeze-dried EPV in 1971

Time of spray	Tree species	Percent population reduction due to treatment	Percent current defoliation
Early	wS	82	33
	bF	64	20
Late	wS	68	41
	bF	16	39
Control	wS		81
	bF		72

TABLE V

Percentage virus infection and population reduction in white spruce plots sprayed with NPV in 1971

Time of spray	Percent virus infection NPV	CPV	Percent population reduction due to treatment
Early	21	22	69
Late	41	22	80
Control	0	3	

NPV plots

In the year of application a high incidence of CPV was found in both the early and late spray NPV plots whereas only 2% and 3% CPV were found in two control plots. It was concluded that the NPV which was sprayed must have been contaminated with CPV. The maximum percentages of both viruses are given in Table V, along with the population reduction figures. No foliage protection was obtained on these plots in the year of application.

In the year following application very little virus could be detected until larvae were fully grown. When the results of the 1972 virus infection sampling are compared to the 1971 results as shown in Table VI, it can be seen that the NPV

persisted well, increasing in one plot and declining in another. The CPV declined in both plots. There was also a marked population reduction in the year following application accompanied by a good degree of foliage protection in the late spray plot (Table VII).

TABLE VI

Percentages of virus infection in NPV plots in the year of application and in the following year

Time of spray	Year of sample	Percent virus infection	
		NPV	CPV
Early	1971	21	22
	1972	30	8
Late	1971	41	22
	1972	24	3

TABLE VII

Population reduction and foliage protection in NPV plots in the year following application

Time of spray	Percent population reduction due to treatment	Percent current defoliation
Early	20	82
Late	65	30
Control		81

Discussion

The EPV sprayed near Pembroke in 1971 was heavily contaminated with NPV and CPV and the NPV was heavily contaminated with CPV. It has been demonstrated that CPV has an adverse effect on the development of NPV (Bird, 1969) and it is possible that mixed infections also inhibit EPV. The infection studies and population reduction studies did not give parallel results in the EPV trials.

The infection studies indicated that the early spray gave better results and the population reduction studies indicated that the late spray was better. In the EPV plots better infection and mortality were obtained on white spruce than on balsam fir in the early spray plots. In the NPV plots both methods of assessment showed that, with the heavy concentrations of virus used, a late spray was better. None of the treatments gave satisfactory foliage protection in the year of application and this fact must be accepted in any spruce budworm virus control program.

It was very encouraging to find that virus carry-over had occurred from 1971 to 1972 on both the EPV and NPV plots near Pembroke. In the EPV plots there was a very marked decrease of the EPV and an increase in NPV; in the NPV plots this virus persisted well and the CPV declined. It is concluded that EPV contaminated with NPV and CPV does not carry-over well from one year to the next. It has been shown in the laboratory that dual infections of EPV and NPV result in fairly rapid death from NPV before EPV symptoms are exhibited. In British Columbia, where the entomopoxvirus was discovered, transmission of this virus occurs from one year to the next at very low population densities. The mode of transmission of the NPV is not clearly understood, but it is possible that viral inclusion bodies remain infectious throughout the winter on the foliage or in cadavers which remain adhering to the trees.

In the year following application a high degree of foliage protection was obtained in the late spray NPV plot. Good protection was also obtained on the two heaviest concentration EPV plots. Marked population reductions were obtained on many of the plots studied, particularly on white spruce hosts, and these results illustrate that spruce budworm virus spray trials must be continued and the results evaluated on a long-term basis.

To date very high dosages of virus have been applied on the plots sprayed with NPV and such dosages on an operational basis would be economically unacceptable. It was unfortunate that viruses sprayed in 1971 were contaminated, but in spite of this it appears that NPV carries over well even in mixed infections and it is potentially useful in the control of spruce budworm. The program will continue with an emphasis on NPV and lower, more operationally realistic application rates will be tested.

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PARASITISM OF ADULT *NOTOXUS ANCHORA* HENZ. (COLEOPTERA: ANTHICIDAE) BY *SYRRHIZUS AGILIS* (CRESS.) (HYMENOPTERA: BRACONIDAE).

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Abstract

Adults of the flower beetle *Notoxus anchora* Henz., feeding on alfalfa were parasitized by the braconid *Syrrhizus agilis* (Cress.) near Belleville, Ontario.

* * * * * *

Notoxus anchora Henz., is a common anthicid beetle feeding on alfalfa and was found in other agricultural habitats including oat and wheat fields in the Belleville, Ontario district. In late June, 1964, first-instar braconid larvae were dissected from adult *N. anchora;* three of 42 beetles were parasitized. Rearings from field collections in 1965 revealed that the parasite larvae were *Syrrhizus agilis* (Cress.). This is the first host record of *S. agilis* and the second record of parasitism of adult Anthicidae (Gornitz 1937). Other known associations of *Syrrhizus* were listed by Shenefelt (1969).

The collections of *N. anchora* in 1965 were obtained from alfalfa. Some adults were dissected to determine parasite incidence and development and others were held at 23°C for parasite larval emergence. On June 17, of 33 adults dissected none was parasitized; June 21, 17 dissected, 1 parasitized (first-instar larva); and on July 22, 15 dissected, 2 parasitized (1 immature, 1 mature egg). From approximately 100 *N. anchora* adults collected June 21-25, 5 larvae emerged and 4 spun cocoons from which *S. agilis* females emerged 10-11 days later.

As suggested by its name, *S. agilis* is a nimble, fast-moving species, similar to *N. anchora* which is highly mobile and which also conceals itself in debris or soil cracks. An individual of *S. agilis* which finds a flower beetle, grasps the elytra of the beetle's abdomen and positions itself sideways on top. It then curves its gaster downwards and thrusts the ovipositor between the anterior sternites into the haemocoel.

Specimens of *N. anchora* dissected in June appeared teneral and none were gravid until early July. Presumably, adults develop from these eggs, overwinter, and some contain the first-instar of the braconid. Additional dissections and rearings are needed to indicate clearly the life cycles of both species of this association.

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THE INTRINSIC RATES OF NATURAL INCREASE OF *TROGODERMA INCLUSUM* LECONTE AND *TROGODERMA VARIABILE* BALLION (COLEOPTERA:DERMESTIDAE)

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Abstract

The intrinsic rates of natural increase of *Trogoderma inclusum* Leconte and *Trogoderma variabile* Ballion (Coleoptera:Dermestidae) were determined under four different sets of conditions namely:

(1) variable temperature and variable relative humidity (17 to 28°C and 10 to 82 per cent R.H.).

(2) medium temperature and variable humidity (29 ± 1°C and 44 to 72 per cent R.H.).

(3) high temperature and constant humidity (35 ± 2°C and 70 ± 2 per cent R.H.), and a photoperiod of 12 hours.

(4) sub-lethal temperature and constant humidity (40 ± 2°C and 70 ± 2 per cent R.H.), and a photoperiod of 12 hours.

Mean fecundity, percentage survival, and speed of development varied with environmental conditions. Generally, the highest mean fecundity, greatest survival, and the fastest rate of development occurred at 29 ± 1°C and 44 to 72 per cent relative humidity. Both species had a similar mean rate of development (egg to non-reproductive adult) but differed greatly in the mean percentage survival.

The rate of increase, λ, was most rapid for both species at 29 ± 1°C and 44 to 72 per cent relative humidity. *T. inclusum* and *T. variabile* had a finite rate of natural increase (λ) of only 1.0528 and 1.0307 per week respectively and it seemed unlikely that these two species would become very serious pests of stored products in Canada because of low winter temperature and relatively short summers.

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Introduction

Of the six subfamilies in the Dermestidae, the members of the Anthreninae, to which *Trogoderma* belongs, are the most numerous, the most successful, and the most specialized (Hinton, 1945). Dermestids feed on a great variety of materials of both animal and vegetable origin. The majority of these beetles normally live on animal matter or materials containing animal proteins. The natural habitats of some species are the nests of bees, wasps, birds and rodents and the webs of caterpillars and spiders. Originally, the species that are pests of stored products have come from

such breeding places or from other natural habitats and they are transferring their activities continually from dead animals, or the nests of birds and insects to stored products.

Explanations have been sought as to why and how populations of organisms increase and decrease and, what factors, mechanisms, or processes, if any, are responsible for the control of the numbers of a species. Many authors, including Malthus and Darwin, have been concerned with these phenomena. In 1839 the Belgian mathematician Verhulst suggested the use of a curve called the 'logistic curve' to describe the growth of human populations. Some biomathematicians have since modified the logistic curve to explain different aspects of population growth. The modern development of this branch of population mathematics was probably due to A.J. Lotka (1925) who originated the concept of 'the intrinsic rate of natural increase'. Lotka's methods were modified later for application to lower mammals (Leslie and Ranson, 1940) and for insects (Birch, 1948, Leslie and Park, 1949). Howe (1953) used a method called the "primitive (single oviposition period) method" for determining the finite rate of natural increase ($\hat{\lambda}$) of an insect species which laid all its eggs in a very short period of time.

There are two basic factors that determine an animal's capacity to increase in numbers, firstly, a certain intrinsic characteristic of the organism called the innate capacity for increase and secondly, environmental factors (Andrewartha and Birch, 1954). The three components of the intrinsic factor are longevity, fecundity, and speed of development. The rate of increase or decrease of a population is dependent on the interactions between the intrinsic and environmental factors. The interaction can be measured quantitatively, the index of interaction, r, being called "the intrinsic rate of natural increase".

The life stages and taxonomy of *T. inclusum* and *T. variabile* have been described by Hinton (1945), Beal (1954, 1956), Hadaway (1956), Howe and Burges (1956), Loschiavo (1960), and Mroczkowski (1968). Both species have been recorded as pests of stored grains in North America. Canada is a major producer of grains, and consequently a large proportion is stored in warehouses throughout the year. There is therefore the probability of serious infestations by these insects.

The present study of the intrinsic rates of natural increase was to assess the potential economic importance of these two species in Canada.

Materials and Methods

The intrinsic rates of natural increase of *T. inclusum* and *T. variabile* were determined under four different environmental conditions namely:

(a) 17 to 28°C and 10 to 82 per cent R.H.

(b) 29 ± 1°C and 44 to 72 per cent R.H.

(c) 35 ± 2°C and 70 ± 2 per cent R.H. and a photoperiod of 12 hours.

(d) 40 ± 2°C and 70 ± 2 per cent R.H., and a photoperiod of 12 hours.

These treatments were chosen because:

(1) variable temperature and variable R.H., represented more closely the conditions that exist in the warehouses during part of the life of the insect whereas

(2) 29 ± 1°C and 44 to 72 per cent R.H., were close to the optimum conditions reported for the multiplication of the species and

(3) 35 to 40 ± 2°C and 70 ± 2 per cent R.H., were the upper limits of temperature tolerance recorded for these insects.

Cultures of *T. inclusum* and *T. variabile* were maintained at 17 to 28°C and 10 to 82 per cent R.H., and at 29 ± 1°C and 44 to 72 per cent R.H. Specimens for experiments at 17 to 28°C and 10 to 82 per cent R.H., were obtained from cultures reared under these environmental conditions whereas specimens for other experiments were reared at 29 ± 1°C and 44 to 72 per cent R.H. Pupae were isolated, one pupa to a petri dish (50 mm diameter x 15 mm deep), and after their development into adults, a male and a female of similar age were paired and reared separately on mouse-chow. From the pupae and these pairs of adults, data were obtained on age-specific fecundity, age-specific longevity, and on the pre-emergence, pre-oviposition and oviposition periods. Data were collected daily at 9:00 a.m., for each pair. Adults that had oviposited during the preceding 0 to 24 hours were moved to new containers with fresh food. Upon hatching, some first-instar larvae were reared individually whereas others were reared in groups to determine if the interactions of individuals affected the rate of development. The amount of food was non-limiting. Exuviae were removed after each moult and used to determine the number of larval instars and their duration. At the onset of pupation, pre-pupae from larvae reared in groups were segregated individually and these pupae, in addition to pupae from larvae reared singly, provided the data on the pupal period. Observations were made daily on the eggs, larvae, and pupae to determine their speed of development.

The primitive, single-period method of Howe, (1953) was selected for the calculation of *r*. The basic requirements and their symbols are:

(1) The mean developmental period, egg to non-reproductive adult (d).

(2) The mean length of the oviposition period (l). All eggs were assumed to have been laid at the mid-point of the oviposition period ($0.5\ l$).

(3) Mean fecundity and survival rate (*np*).

Thus if the developmental period of the species was d units and the oviposition period was l units, all eggs of the next generation were assumed to have been laid after $d + 0.5\ l$ periods. A female that laid 2 *n* eggs of which a proportion *p* matured, and the sex ratio of the offspring was unity, produced *np* mature female offspring. Hence it was assumed that each female produced *np* female offspring in $d + 0.5\ l$ periods so that the self-multiplicative rate of increase was calculated as $\lambda = (d + 0.5\ l)$th root *np*. The parameter *r* is the natural logarithm of the parameter λ, hence $r = \log_e \lambda$.

From studies on the biology of an insect species, data can be translated into a general statement about the rate at which the species can increase in numbers. This is determined by substituting the mean value of speed of development plus the mid-point of the oviposition period ($d + 0.5\ l$) and the number of female offspring produced per female (*np*) into the equation $\lambda = (d + 0.5\ l)$th root *np*. Having determined the value of λ, the value of *r* is obtained by substituting the value of λ in the equation $r = \log_e \lambda$

Results

Life-history

The Egg

Eggs were deposited singly on, near to, or under the food. Both species laid eggs at 17 to 28°C and 10 to 82 per cent R.H., at 29°C and 44 to 72 per cent R.H., and at 35°C and 70 per cent R.H. Whereas *T. inclusum* oviposited 12.0 eggs per female at 40°C and 70 per cent R.H., none was laid by *T. variabile*. Those deposited by *T. inclusum* did not hatch.

The incubation period of eggs of both species varied at each environmental condition. The longest, mean-period of incubation occurred at 17 to 28°C and 10 to 82 per cent R.H., whereas the shortest was at 35°C and 70 per cent R.H., (Table I). There were no differences between species at 29°C and 44 to 72 per cent R.H., nor at 35°C and 70 per cent R.H. *T. inclusum* and *T. variabile* had long incubation periods, 14.6 and 17.9 days respectively, when neither temperature nor relative humidity was controlled (Table I).

TABLE I. Developmental period (in days) of the immature stages of *Trogoderma inclusum* Lec., and *Trogoderma variabile* Ball., (Coleoptera: Dermestidae) at different environmental conditions.

Environmental Conditions		Incubation		Larval		Pupal	
		Mean	Range	Mean	Range	Mean	Range
17 to 28°C and 10 to 82% R.H.							
	T. inclusum	14.6	12-19	251.5	87-468	8.2	4-12
	T. variabile	17.9	13-22	72.1	46-194	7.7	4-12
29 ± 1°C and 44 to 72% R.H.							
	T. inclusum	7.1	5-9	35.3	18-142	3.9	3-6
	T. variabile	7.5	6-9	35.2	22-89	4.1	3-5
35 ± 2°C and 70 ± 2% R.H.							
	T. inclusum	5.8	5-6	94.9	61-131	3.0	3-3
	T. variabile	6.2	5-7	*	61-131	3.0	3-3

*Larvae in 'delayed pupation'

The Larva

The speed of development of larvae varied within and between species at the environmental conditions studied. The shortest, mean-period for both species was at 29°C and 44 to 72 per cent R.H., where *T. inclusum* took 35.3 days and *T. variabile* 35.2 days (Table I). The longest, mean-rates of development of both species were at 17 to 28°C and 10 to 82 per cent R.H., with *T. inclusum* taking 251.5 days and *T. variabile* 72.1 days (Table I). The larvae of *T. variabile* failed to pupate at 35°C and 70 per cent R.H., whereas *T. inclusum* averaged 94.9 days for larval development under these conditions.

For each situation a proportion of the larvae reached maturity but failed to pupate (Table II). These larvae were said to be in 'delayed pupation' (Burges, 1961). This phenomenon occurred in 3.4 per cent of *T. inclusum* at 29°C and 44 to 72 per cent R.H., 56.0 per cent at 17 to 28°C and 10 to 82 per cent R.H., and 49.3 per cent at 35°C and 70 per cent R.H. *T. variabile* had 14.6, 37.5 and 100 per cent respectively in delayed pupation at these conditions. Another aspect of this phenomenon was the decrease in size of larvae at each moult. Some larvae grew to what appeared to be fourth instar and then decreased in size at each moult until they became smaller than first-instar larvae. All these larvae died eventually. This pattern of retrogression was observed among fully developed larvae which were in a state of 'delayed pupation'.

TABLE II. The number and percentage larvae of *Trogoderma inclusum* Lec., and *Trogoderma variabile* Ball., (Coleoptera:Dermestidae) that 'delayed pupation' and the mean number of days and moults per larva in delayed pupation at different environmental conditions.

Environmental Conditions		No. of mature larvae	Larvae in 'delayed pupation' Number	Percentage	Mean no. of days	Mean no. of moults
17 to 28°C and 10 to 82% R.H.						
	T. inclusum	1080	605	56.0	414	14
	T. variabile	224	84	37.5	381	15
29 ± 1°C and 44 to 72% R.H.						
	T. inclusum	760	26	3.4	413	31
	T. variabile	303	43	14.2	385	30
35 ± 2°C and 70 ± 2% R.H.						
	T. inclusum	71	35	49.3	149	—
	T. variabile	24	24	100.0	148	—

The Pupa

For the conditions under which pupation occurred, the longest, mean-rate of development for both species was at 17 to 28°C and 10 to 82 per cent R.H.; *T. inclusum* requiring 8.2 days and *T. variabile* 7.7 days. The shortest period for *T. inclusum* was 3.0 days at 35°C and 70 per cent R.H., whereas that for *T. variabile* was 4.1 days at 29°C and 44 to 72 per cent R.H., (Table I).

The Adult

The adult developed within the last larval skin which split longitudinally at pupation to accommodate the pupa. The time spent by adults, before emerging from the last larval skin, was variable (Table III). The longest period spent by *T. inclusum* was 4.7 days and *T. variabile* 4.0 days at 17 to 28°C and 10 to 82 per cent R.H. The shortest period for *T. inclusum* was 1.0 days at 35° and 70 per cent R.H., whereas that for *T. variable* was 2.1 days at 29°C and 44 to 72 per cent R.H. The mean, pre-oviposition period of *T. inclusum* varied from 7.9 days at 17 to 20°C and 10 to 82 per cent R.H., to 1.8 days at 35°C and 70 per cent R.H., whereas that of *T. variabile* varied from 9.3 days at 17 to 28°C and 10 to 82 per cent R.H., to 2.3 days at 29°C and 44 to 72 per cent R.H., (Table III).

The mean number of days of the oviposition period at 29°C and 44 to 72 per cent R.H., was 5.5 days for *T. inclusum* and 5.2 days for *T. variabile* (Table III). The shortest, mean period for *T. inclusum* was 4.5 days at 35°C and 70 per cent R.H., and for *T. variabile* 5.2 days at 29°C and 44 to 72 per cent R.H. The greatest variability within species was 1 to 20 and 6 to 16 days for *T. inclusum* and *T. variabile* respectively and the longest mean-period for each species was 8.8 days for *T. inclusum* and 9.7 days for *T. variabile* at 17 to 28°C and 10 to 82 per cent R.H., (Table III).

TABLE III. Mean and Range (in days) spent by the non-reproductive and the mature ovipositing adults of *Trogoderma inclusum* Lec., and *Trogoderma variabile* Ball., (Coleoptera:Dermestidae) during the pre-emergence, pre-oviposition and oviposition periods at different environmental conditions.

Environmental Conditions		Non-Reproductive Adult				Mature Adult	
		Pre-emergence		Pre-oviposition		Oviposition	
		Mean	Range	Mean	Range	Mean	Range
17 to 28°C and 10 to 82% R.H.							
	T. inclusum	4.7	2-22	7.9	5-15	8.8	1-20
	T. variabile	4.0	1-11	9.3	6-14	9.7	6-16
29 ± 1°C and 44 to 72% R.H.							
	T. inclusum	2.2	1-5	2.5	2-5	5.5	1-9
	T. variabile	2.1	1-4	2.3	1-3	5.2	1-10
35 ± 2°C and 70 ± 2% R.H.							
	T. inclusum	1.0	1-2	1.8	1-3	4.5	2-9
	T. variabile	*					

*No adult progeny (F_2) for testing

TABLE IV. Fecundity of *Trogoderma inclusum* Lec., and *Trogoderma variabile* Ball., (Coleoptera:Dermestidae) adults of similar age and the survival-rates of their progeny at different environmental conditions.

Environmental Conditions		no. of pairs	no. of eggs	no. of larvae	no. of pupae	Adults	
						Female	Male
17 to 28°C and 10 to 82% R.H.							
	T. inclusum	41	2782	1185	436	190	242
	Mean		67.9	24.6	10.6	4.6	5.9
	Range		0-171	0-131	—	—	—
	T. variabile	12	935	152	120	60	60
	Mean		77.9	12.7	10.0	5.0	5.0
	Range		10-181	0-57	0-43	0-22	0-24
29 ± 1°C and 44 to 72% R.H.							
	T. inclusum	23	2274	1100	734	362	366
	Mean		98.9	47.8	31.9	15.8	15.9
	Range		0-193	0-108	0-57	0-31	0-32
	T. variabile	25	2675	381	260	127	131
	Mean		107.0	15.2	10.4	5.1	5.2
	Range		0-168	0-36	0-33	0-17	0-16
35 ± 2°C and 70 ± 2% R.H.							
	T. inclusum	10	771	268	36	17	18
	Mean		77.1	26.8	3.6	1.71	1.8
	Range		15-134	0-84	—	—	—
	T. variabile	13	747	41*	0	0	0
	Mean		57.5	3.2	—	—	—
	Range		0-128	0-11	—	—	—

*All larvae in 'delayed pupation'

The fecundity of females varied within and between species (Table IV). The highest, mean number of eggs per female of 98.9 and 107.0 were laid by *T. inclusum* and *T. variabile* respectively at 29°C and 44 to 72 per cent R.H., and the lowest for *T. inclusum* was 12.0 eggs per female at 40°C and 70 per cent R.H. The mean fecundity of *T. inclusum* was 9.2 eggs greater at 35°C and 70 per cent R.H., than at 17 to 28°C and 10 to 82 per cent R.H. *T. variabile* laid 20.4 more eggs per female at 17 to 28°C and 10 to 82 per cent R.H., than at 35°C and 70 per cent R.H.

The intrinsic rate of natural increase of *T. inclusum* and *T. variabile* was highest at 29 ± 1°C and 44 to 72 per cent R.H., where λ was 1.0528 and 1.0307 per week for *T. inclusum* and *T. variabile* respectively (Table V) and lowest at 40 ± 2°C and 70 ± 2 per cent R.H., where no adult progeny were obtained.

TABLE V. The finite rate of increase per week (λ) and the intrinsic rates of natural increase (*r*)* of *Trogoderma inclusum* Lec., and *Trogoderma variabile* Ball., (Coleoptera:Dermestidae) at different environmental conditions.

Environmental Conditions		*r*	λ
17 to 28°C and 10 to 82% R.H.			
	T. inclusum	0.00524	1.00525
	T. variabile	0.0139	1.0140
29 ± 1°C and 44 to 72% R.H.			
	T. inclusum	0.0515	1.0528
	T. variabile	0.0303	1.0307
35 ± 2°C and 70 ± 2% R.H.			
	T. inclusum	0.00487	1.0050
	T. variabile	0.08	0.0

*$r = \log_e \lambda$

TABLE VI. Mean speed of development (in days) and the oviposition period (in days) of *Trogoderma inclusum* Lec., and *Trogoderma variabile* Ball., (Coleoptera:Dermestidae) at different environmental conditions.

Environmental Conditions		Eggs	Larvae	Pupae	Pre-emergence	Pre-oviposition	Mid-point of oviposition period	Total
17 to 28°C and 10 to 82% R.H.								
	T. inclusum	14.6	251.5	8.2	4.7	7.9	4.4	291.3
	T. variabile	17.9	72.1	7.7	4.0	9.3	4.9	115.9
29 ± 1°C and 44 to 72% R.H.								
	T. inclusum	7.1	35.3	3.9	2.2	2.5	2.8	53.8
	T. variabile	7.5	35.2	4.1	2.1	2.3	2.6	53.8
35 ± 2°C and 70 ± 2% R.H.								
	T. inclusum	5.8	94.9	3.0	1.0	1.8	2.3	108.8
	T. variabile	6.2	*					

*All larvae in 'delayed pupation'

Discussion

The present study has determined some of the effects of temperature and humidity on fecundity and survival rate, speed of development, and the intrinsic rate of natural increase of *T. variabile* and *T. inclusum*. The effects of temperature on the fecundity of *T. variabile* have been investigated thoroughly by Loschiavo (1967); and to a lesser extent, survival-rate and the speed of development, (Loschiavo, 1960: Burges, 1961). Hadaway (1956) studied the effects of temperature and humidity on the life-stages of *T. inclusum*. The present study has covered a narrower range of temperature and humidity. The mean fecundity of both species, which was greatest at 29 ± 1°C and 44 to 72 per cent R.H., increased with temperature up to 30°C and then declined (Loschiavo, 1967; Hadaway, 1956). Loschiavo found that mean egg production of *T. variabile* was greatest at 27.5 and 30°C. Hadaway suggested that 30°C was the optimum temperature for maximum fecundity by *T. inclusum*. At constant temperatures the number of eggs of *T. inclusum* increased with an increase in the humidity (Hadaway, 1956).

At 29 ± 1°C and 44 to 72 per cent R.H., the mean total period of development and oviposition for both species were the same (Table VI), although there were variations between species in the mean rates of development of the different life-stages. Although the mean fecundity of *T. variabile* was greater than that of *T. inclusum*, the percentage survival from egg to mature adult female of *T. inclusum* was more than three times as great as that of *T. variabile*. One factor which differentiated the two species and was responsible primarily for the differences in rate of increase was the higher percentage survival of *T. inclusum*.

The mean rate of development of *T. inclusum* at 35°C and 70 per cent R.H., was more than twice that at 29°C and 44 to 72 per cent R.H. The mean fecundity and the mean survival-rate were much lower at 35°C and 70 per cent R.H., than at 29°C and 44 to 72 per cent R.H. No adults were produced by *T. variabile* at 35°C and 70 per cent R.H. Thus the three components of *r* were much more adversely affected by 35°C and 70 per cent R.H., than by 29°C and 44 to 72 per cent R.H.

In the present investigation neither species produced adults at 40°C and 70 per cent R.H. Hadaway (1965) obtained adults of *T. inclusum* at 40°C but above 73 per cent R.H. In contrast to the present work, Burges (1961) obtained viable eggs of *T. variabile* at 40°C and 70 per cent R.H. Loschiavo (1967) reported that no eggs were deposited by *T. variable* at 40°C and 70 ± 5 per cent R.H. The larvae in Burges' experiment died in an early instar. Burges (1961) reported that all larvae, except three, entered the delayed pupation condition at 35°C and 70 per cent R.H. In the present investigation all larvae were in delayed pupation at 35°C and 70 per cent R.H. It appeared that temperatures of 35°C and above were outside the upper limits of the favourable zone for both species.

Under variable laboratory conditions (17 to 28°C and 44 to 72 per cent R.H.) the mean rates of development of *T. variabile* and *T. inclusum* were much greater than those at 29°C and 44 to 72 per cent R.H. However, there was little difference in percentage survival of *T. variable* at these two conditions although the mean fecundity was much higher at 29°C and 44 to 72 per cent R.H. The percentage survival of *T. variabile* was equally low at 17 to 28°C and 10 to 82 per cent R.H., and at 29 ± 1°C and 44 to 72 per cent R.H. It may have been that recurrent periods of temperatures of 17°C and humidities of 10 per cent were responsible for the much slower rates of development. Burges (1961) found that growth of *T. variable* was very slow at 17.5°C and Loschiavo (1967) suggested that populations of *T. variabile* could not increase at a temperature of 17.5°C or lower. The range of 17 to 28°C and 10 to 82 per cent R.H., was more favourable for *T. variabile* than for *T. inclusum*.

Generally, 29°C and 44 to 72 per cent R.H., was more favourable than the other environmental conditions studied on the components of the innate capacity for increase. The mean rate of development was most rapid and the mean fecundity was highest at 29°C and 44 to 72 per cent R.H. The general pattern of survival-rates of *T. inclusum* and *T. variabile* was low at all the environmental conditions studied. The survival-rates of *T. variabile* at 29°C and 44 to 72 per cent R.H., and at 17 to 28°C and 10 to 82 per cent R.H., were approximately the same. This may indicate that the species generally has a low survival-rate. Compared with 29°C and 44 to 72 per cent R.H., the other environmental conditions were much more severe on the components of *r;* temperature was most critical at 40°C and to a lesser extent at 35°C and 70 per cent R.H. It may be that the adverse effects of higher temperatures may be ameliorated by humidities above 70 per cent. Thus temperature and/or humidity may affect any or all of the components or *r* and thereby have the necessary attributes to determine the rate of increase of a species.

In the present study the finite and the intrinsic rates of natural increase of *T. variabile* were rather low at all conditions as compared to the values of λ obtained by Burges and Loschiavo. The greatest rate of increase occurred at 29°C and 44 to 72 per cent R.H., where λ was 1.0528 per week. Burges (1961) and Loschiavo (1967) obtained a factor of 1.7 per seven days and 1.7 per eight days at 30°C and 60 to 70 per cent R.H., and at 32.2 $\pm$ 0.3°C and 70 per cent R.H., respectively. Although the conditions of Burges' and Loschiavo's experiments were not strictly comparable with the present studies some comparisons can be made between their reported rates of increase at 30 and 32°C and those of the present study at 29 $\pm$ 1°C and 44 to 72 per cent R.H. The values of λ at 30°C and 32°C were much greater than at 29°C. The principal differences in the components of λ at 30° (Burges, 1961) and the present study at 29 $\pm$ 1°C was the mean number of female offspring produced per female and to a lesser extent, the mean rate of development, which accounted for the differences in the values of λ . Loschiavo (1967) suggested that 30°C was close to the optimal temperature for development. These experiments did not indicate what the optimum humidity for *T. variabile* was but it seemed unlikely that the lower relative humidities in the present study would account for the differences in the value of λ . Probably the much larger percentage mortality in the egg stage in this experiment was the primary factor responsible for a lower value of λ . The difference in egg mortalities was due to the methods of obtaining eggs. Burges' and Loschiavo's experiments were apparently designed to eliminate some of the natural mortality factors of the egg whereas the present study was designed to obtain approximate values of 'normal' fecundity and percentage survival.

All the major components of the innate capacity for increase were affected adversely by one, some, or all four environmental conditions. The contributions of each component to the value of *r* varied from one environment to the other. Generally, the survival-rate was low and its contribution to *r* was correspondingly low. The value of *r* which accrued from the speed of development was much higher at 29°C and 44 to 72 per cent R.H., than at 35°C and 70 per cent R.H., and at 17 to 28°C and 10 to 82 per cent R.H. Thus, one major component was severely affected by 29°C and 44 to 72 per cent R.H., whereas both components were very severely affected by 35°C and 70 per cent R.H. and at 17 to 28°C and 10 to 82 per cent R.H. The values of the components of *r* were rather low consequently the rate of increase was rather low even at 29°C and 44 to 72 per cent R.H., which approximated relatively favourable conditions for the increase of the species. The present investigation supports Loschiavo's view that "in Canada *T. variabile* is unlikely to become a serious pest of stored grain because of low winter temperatures and

relatively short summers in the primary grain-growing regions" (Loschiavo, 1967). The same may be said of *T. inclusum*. For these species to be very serious pests they would have to make the necessary physiological and behavioural adaptations to increase *r*.

It seems axiomatic that 'in order for a species to survive in a particular environment it may need to have evolved a certain minimum value for its intrinsic rate of natural increase' (Birch, 1948). Birch indicated that, in the evolution of a species, *r* could be attained along more than one route, since it has a number of component variables; viz., the duration of development of the immature stages, the survival-rate of immature stages, the adult life expectancy, and the age specific fecundity schedule. These components affect the value of *r* differently. The various values of these innate qualities may vary intermittently due to changing severity and favourability of the components of the environment sometimes causing population fluctuations and sometimes stability. This continuous interplay of the components of an animal's environment and the components of its innate capacity for increase determine *r* and thereby constitute the mechanism whereby numbers of organisms are determined or maintained in nature.

The primitive, single oviposition-period-method was used because the experimental animals fit the criteria set for this method (Howe, 1953). It appeared as if the Leslie-Birch method was most appropriate for organisms with long oviposition cycles. Howe's method enables estimates to be made with greater speed and with an accuracy which is sufficient for most purposes (Andrewartha and Birch, 1954). It has been suggested that the mathematics of the Leslie-Birch method requiring trial and error solutions of exponential equations may deter many biologists from using this valuable parameter, *r* (Howe, 1953). The biologists who have attempted to estimate *r* recently have used Howe's method.

A knowledge of *r* gained in the laboratory under diverse environmental conditions may be of value in economic entomology. An extrapolation can be made of the possible rates of increase in nature if the microclimatic conditions in the field have been determined. A knowledge of the intrinsic rates of natural increase of local populations of a species under different environmental conditions may throw light on differences of genotypes of these populations.

A study of the finite or the intrinsic rates of natural increase of an insect predator under different conditions may provide an index of the relative suitability of different environments in nature for the species and thereby, at least partly, eliminate the 'hit and miss' method used in applied biological control work in the introduction of a predator into an area to control a pest species.

Information on the age-specific fecundity of an insect may have practical value. In mass propagation of insects this information can be used to a great advantage. If for instance, 87 per cent of all eggs are laid in one week and the remainder is oviposited within two weeks it may be economical to discard the females after a week of oviposition. This ensures a rapid turnover and this seems to be a crucial need in the sterile-male release technique. It may be equally suitable in mass propagation of predators for establishment in a new area to control an introduced insect pest.

In terms of a rationale for population dynamics the concept of the intrinsic rate of natural increase may be of vital importance. Cole (1954) has stressed the importance of Lotka's mathematical models in providing the methods for establishing the relationships between life-history features and their population consequences. The evolutionary significance of this analysis has been emphasized more recently by Connell, Mertz and Murdoch (1970).

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BEHAVIOURAL STUDIES ON QUEEN INTRODUCTION IN HONEY BEES* (*APIS MELLIFERA* L.)

V. BEHAVIOURAL RELATIONSHIP BETWEEN PAIRS OF QUEENS WITHOUT WORKER ATTENDANTS.**

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Abstract

Aggression between pairs of honey bee queens (*Apis mellifera* L.) was much more pronounced between two queens of similar age and condition than between those of different age and condition (laying or virgin). Mandibular gland removal did not affect this aggressive tendency, nor did previous fighting experience. Hostility of

*Hymenoptera: Apidae.

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queens was not related to their weights. However, starvation of the queen seemed to lower her agressiveness. The initial attacker was usually the victor and was unharmed in the encounter. Three basic behaviour patterns in the encounter between two queens were observed: aggression, non-aggression and avoidance.

The significance of the results in relation to the social organization of honey bee colony is discussed.

* * * * * *

Introduction

It is generally accepted that honey bee queens (*Apis mellifera* L.) are agressive towards each other. Huber (1792) and Davis (1908) observed fighting among queens of different ages. Skirkyavichyus (1965) reported that queens of the same age behaved aggressively towards one another but those of different ages did not exhibit this behaviour pattern. If similar queens were introduced into the same box with workers, the queens soon started a fight which always ended in the death of one. The worker bees took no part in the contest. However, when the queens' age and condition differed, they showed no hostility to one another, and the fate of the queens was determined by the workers which eliminated one of them. Minnick *et al.*, (1967) observed that the workers eliminated mated or laying queens introduced into queenright observation hives. They found that the established queens and the introduced virgin queens were without any antagonism.

Velthuis (1967) observed that queens without mandibular glands and with the abdominal tergites covered with nail polish did not react to each other, whereas queens, from which only mandibular glands were extirpated, fought immediately after they met. He suggested that the products of the dermal glands on the tergites of the abdomen were involved in the mutual recognition of queens. Gary *et al.*, (1967) found that the stinging response became extinct within 90 minutes after continued contact with other queens. Riedel and Blum (1972) reported that vanilla extract, neat citral and Airwick®, when administered to the antennae of the queens, eliminated aggression between them.

There are conditions in which a colony will tolerate more than one queen. The most common circumstance is after supersedure when the old queen and daughter may live and lay together without enmity (Doolittle, 1908; Kelsall, 1940; Taranov, 1951). There is a method of colony management in which two queens are used (Haydak and Dietz, 1967).

In the present study the behaviour of pairs of queens was observed in laboratory cages. The study was an attempt to analyze some of the factors which may be important in the aggressive behaviour of queens towards each other.

Materials and Methods

The experiments were conducted at the University of Guelph, Ontario, during Oct., 1969, and from June until Oct. 1970, using Carniolan queens (*Apis mellifera carnica* Pollman) of known ages. A modified Doolittle (1915) method of queen rearing was used to obtain the queens. They were reared from less than 1-day-old larvae in strong queenless colonies, with 30 grafted queen-cell cups per colony. On emergence each queen was marked on the thorax with acetone-soluble Duco laquer paint. Each queen was caged singly, without worker attendants and with candy in standard Benton queen-mailing cages (for a description of this cage see Snelgrove, 1940). Each cage was corked at both ends and covered with 12-mesh wire screen.

The virgin queens were held, until required, in the middle of queenless colonies. A normal Langstroth frame was modified to hold 52 caged queens in each colony.

One hundred and fifty 2-, 3-, and 4-frame nuclei (Langstroth frames) were used for queen mating. To obtain mated laying queens, the newly-emerged and marked virgin queens were introduced into the nuclei in a Benton mailing cage with a candy plug.

Perspex cages with internal dimensions of 6.3 cm x 9.0 cm x 5.1 cm were used in the laboratory experiments. The 5.1 cm x 9.0 cm top panel was removable and the others were glued together. The bottom panel was covered with plastic comb-foundation. The side panels were punched with several 2 mm holes for ventilation.

According to the specific experiment the queen was placed into a small vial and weighed on a Mettler HIOT analytical balance, to the nearest 0.001g.

Gary's (1961) technique as modified by Walton and Smith (1970) was used for extirpating the mandibular glands. During the operation period the queen was anaesthetized and each gland was removed through an incision in the cuticle of the genal wall. Queens less than 1-day old, and 5-day old queens were operated upon and replaced in their original cages without worker attendants and then returned to the holding colony. Sham-operated queens received the same treatment as the operated queens except that the glands were not removed.

The perspex cages were placed on a laboratory bench and the experiments were conducted at room temperature with natural and artificial light. The virgin queens were obtained from the holding colony and the laying queens removed from their nuclei approximately 10 minutes before the commencement of the experiment. The queens were allowed to come out from the mailing cages and each queen was dropped gently through the opening in the top of the perspex cage. Except as otherwise stated, the behaviour of the queens toward each other was observed for 100 minutes, after the introduction of the second queen. The time of the first attack, the number of attacks, the direction of attacks, and the duration of aggressive behaviour was calculated from the time of the first attack until the first non-aggressive approach of the queens to each other. After the termination of each series the numbers of dead and damaged queens were recorded. A queen was regarded as aggressive when she bit or stung the opponent queen. A queen was regarded injured or damaged when she was partially paralyzed or her body was torn or mutilated by the other queen. A queen was considered dead if she was fully paralyzed and no movement of the body or extremities was observed. The system used for scoring aggressive behaviour is given in each table.

The statistical analyses used in this study were those recommended by Steel and Torrie (1960) and Snedecor and Cochran (1967).

Experiment 1. Influence of age and condition of queens on their behaviour towards each other.

One hundred queens were prepared to study the effects of age and condition on their behaviour towards each other. Laying and virgin queens were removed from their respective nuclei or holding colonies. They were immediately paried as in Table I, and the pairs were randomly allocated to the cages. One queen was introduced into each cage and approximately at 2-minute intervals a second queen was introduced. One hundred minutes after introduction of the second queen the number of injured or dead queens was recorded. The results are in Table I and Figure 1. The queens in all treatments displayed aggressive behaviour. Although considerable differences were observed, queens appeared more aggressive when their age and condition was similar. In these groups some queens were injured and dead at the end

of the experiment, whereas when the age and condition of the queens was different no deaths occurred.

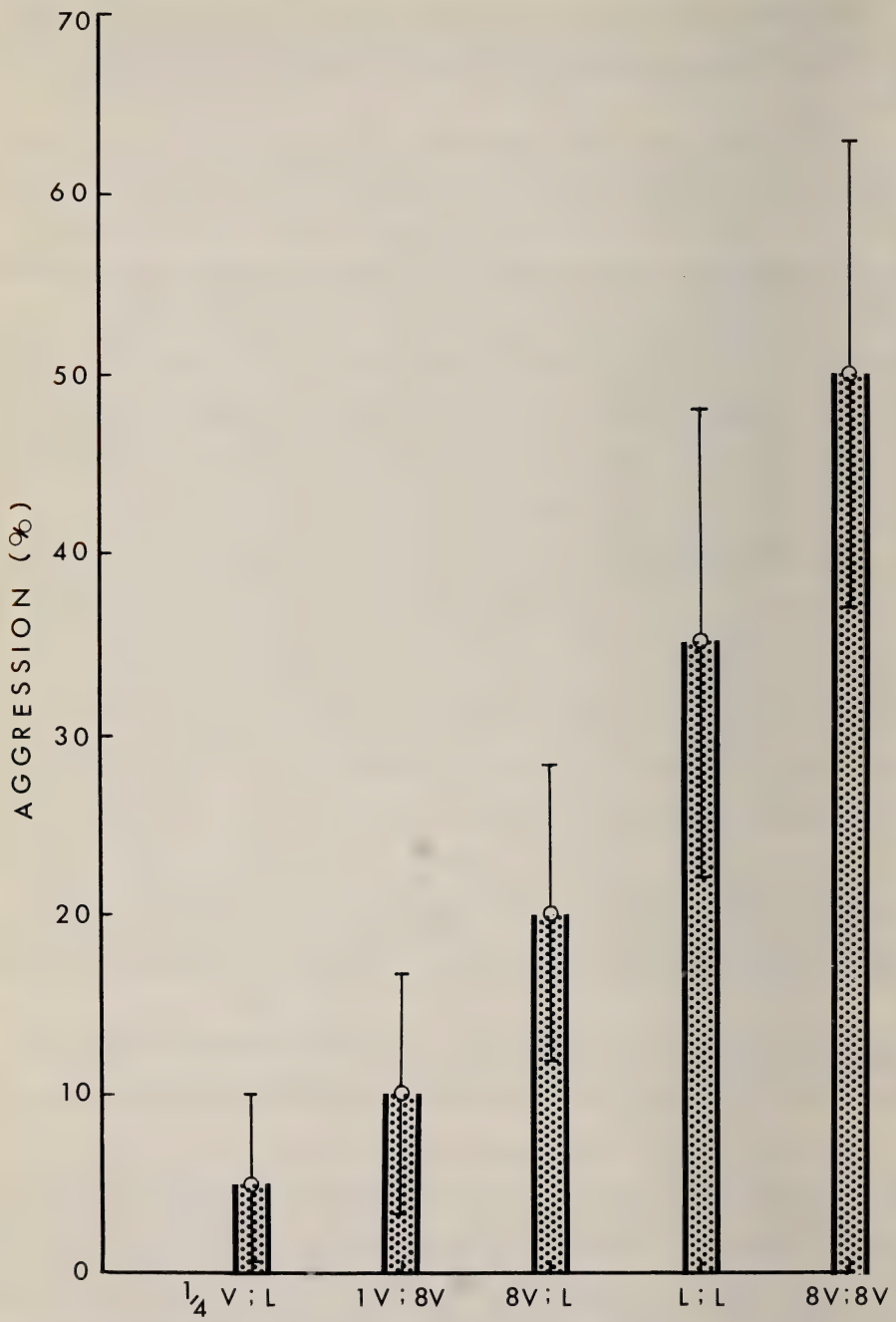

FIGURE 1. Relationship of the aggression of different pairs of queens. Vertical bar = mean aggression of 10 pairs of queens, vertical line = ± S.E. of mean, Arabic numbers = age of the queens in days, V = virgin queens, L = laying queens, and % aggression = the queen injured = 50%, the queen dead = 100%.

TABLE I. Aggression between pairs of honey bee queens of similar and different age and condition.

Treatment[1]	1	2	3	4	5
Condition of queen V = virgin L = laying	V vs L	V vs V	V vs L	L vs L	V vs V
Age in days	1/4 vs 55	1 vs 8	8 vs 55	55 vs 55	8 vs 8
No. of pairs where a queen was rejected:					
injured	1	2	4	3	4
dead	0	0	0	2	3

Chi-square test between all treatments	= 9.68 (0.025 < P < 0.05)*
1 + 2 + 3 vs 4 + 5	= 6.85 (0.005 < P < 0.01)**
4 vs 5	= 0.83 (0.75 < P < 0.9)ns
1 vs 3	= 2.40 (0.1 < P < 0.25)ns

[1] 10 pairs of queens in each treatment.
* Significant.
** Highly significant.
ns Not significant.

Experiment 2: Role of the mandibular gland in queen aggressiveness.

This experiment was an attempt to determine whether or not the removal of the mandibular glands of the queens influenced their hostile attitude towards each other.

Newly emerged queens were caged singly in queen mailing cages without worker attendants and held in queen holding colonies. On the 5th day after emergence, the mandibular glands of 15 queens were removed. Ten queens were sham-operated and 15 normal queens were used as controls. After the operation, the queens were returned to the holding colony for 5 days. The following four treatments were conducted using the 40 prepared, 10-day old queens: (1) queens without mandibular glands, (2) unoperated queens, (3) sham-operated queens and (4) unoperated versus queens without mandibular glands. This procedure was repeated for each of the 3 replications. The experiment was conducted in a randomized complete block design using subsamples. The queens were randomly allocated to the cages. In each treatment 5 pairs of queens comprised a sample and one pair the subsample. One queen was introduced into each cage and at approximately 2-minute intervals the second queen was introduced into each cage. The results are summarized in Table II.

The queens were almost equally aggressive towards each other in the four treatments. To exclude the possibility of contaminating the queen with her own mandibular gland secretion, the experiment was repeated using queens less than 1-day old for gland extirpation, since the mandibular glands do not secrete material to the outside of the body until about 3 days after emergence (Nedel, 1960). The experiment, was repeated on 10-day old queens and the results also given in Table II.

The queens were again aggressive in the four treatments. The weight of the queens were also similar in the four groups.

The direction of attack in the 4th treatment in Table II was analyzed. The operated queen attacked the normal queen first in 8 pairs and the normal queen attacked the operated queens first in 21 pairs (chi-square = 4.97, $P < 0.05$). The operated queen was injured or dead in 22 pairs and the normal one in 2 pairs (chi-square = 15.04, $P < 0.005$). Thus the normal queen usually destroyed the queens without mandibular glands.

TABLE II. Effect of mandibular gland extirpation on aggression between pairs of 10-day old virgin honey bee queens.

Treatment	1	2	3	4
Queens	without mandibular glands	normal	sham operated	without mandibular glands vs normal
Mean % aggression[1,3] (15 pairs of queens in each treatment)	72.1±10.4ns	81.0±9.0	90.0±5.3	74.3±10.3 ns
Mean % aggression[2,3] (15 pairs of queens in each treatment)	48.5± 8.4ns	47.7±6.0	50.3±6.6	58.0±9.1 ns
Mean weight[2] mg/queen	198.3± 6.0ns	178.7±4.1	199.8±5.6	193.7± 4.3 ns

[1] Operations were conducted when queens were 5 days old.

[2] Operations were conducted when queens were 1 day old.

[3] Aggression: the queen dead = 100%, the queen injured = 50% or duration of aggressiveness in minutes = %, during 100 minute observation. Whichever score gave the highest percentage was accepted.

ns The difference of means are not significant ($P < 0.05$)

Experiment 3 : Effect of previous fighting experience on the aggressiveness of queens.

According to Scott (1963) "Mice which won an initial fight and continued to win developed very strong habits of fighting and winning, whereas those which were beaten and continued to lose developed strong habits of running away." In this experiment an attempt was made to test whether the honey bee queens' aggressiveness is affected by previous fighting experience.

Five victorious queens having fought on the previous day were tested against 5 queens with no fighting experience. Five pairs of inexperienced queens served as contols. One pair of queens was introduced into each perspex cage. In a randomized complete-block design the above described process was repeated for each of the 7 replications. The results obtained are presented in Table III.

There was no significant difference between the two treatments. The result suggests that other factor(s) may be more important than the fighting experience.

TABLE III. Aggressiveness between pairs of honey bee queens with no fighting experience and with previous fighting experience.

Treatment	1	2
35 pairs of 7-day old queens in each treatment	inexperienced	inexperienced vs experienced
Mean % aggression[1]	51.2±4.7	65.5±5.8 ns

nsThe difference of means is not significant ($0.05 < P < 0.1$).

[1]Aggression scored as in Table II.

Experiment 4: Relationship between aggressive behaviour and weight.

Eighty pairs of 7-day old queens were observed in separate cages in an attempt to detect the possible role of queen weight in aggressive behaviour. The results appear in Table IV.

TABLE IV. Number of victorious 7-day old honey bee queens classified by weight.

Number of times the victorious queen[1] is: heavier	lighter	no victor	total	Chi-square
23	29	28	80	0.777 ns

[1]Victor = opponent injured or dead

nsNot significant ($0.75 > P > 0.5$).

The small difference between the three groups of queens is apparently due to chance variation. The data were also analyzed according to the queens' weight differences. The pairs of queens were grouped as follows: (1) 0 - 20 mg, (2) 21 - 40 mg, (3) 41 - 60 mg and (4) > 60 mg. The results obtained are shown in Table V.

There was no significant difference between heavier and lighter queens in relation of victory.

TABLE V. Number of victorious honey bee queens classified by the weight difference between queens in a pair.

Weight difference between queens[1] in a pair (mg)	Victor[2] is heavierns	Lighter	Total
0 - 20	11	18	29
21 - 40	4	5	9
41 - 60	7	4	11
> 60	1	2	3

[1]7-day old queens

[2]Victor = opponent injured or dead.

nsChi-square = 2.29 ($0.75 > P > 0.5$), not significant.

Experiment 5 : Relationship between nutrition and behaviour.

Forty-six pairs of queens less than 1 day old were observed for a few minutes after the introduction of a second queen into the perspex cage. All but three of the 46 fought immediately on first contact. The three pairs that did not fight, begged food from each other. This suggested that hungry queens were not aggressive.

Twenty-four queens were prepared to detect the possible role of nutrition on the aggressive behaviour of queens towards each other. The queens were removed from the holding colony and kept in mailing cages for 20 hours, each with 3 attendant workers. Candy was available in 12 cages while 12 cages were without food. After a lapse of 20 hours the aggressive behaviour of pairs of unfed and fed queens were tested. The results are shown in Table VI.

TABLE VI. Aggressiveness between pairs of fed and unfed honey bee queens.

Treatment	1	2
6 pairs of 13-day-old queens in each treatment	fed	unfed
Aggression[1]	76.8 ± 16.6	39.9 ± 19.4 ns

[1]Aggression rated as in Table II.

nsNot significant, ($P > 0.05$).

Although a difference was observed, it was not significant, possibly due to the few replications. Four of the queens could hardly move because of starvation, but were still aggressive. The results of this experiment suggest that the immediate cause of the peaceful food-begging behaviour between queens was hunger.

Experiment 6 : Analysis of the behaviour of one queen towards another queen.

The behaviour of 80 pairs of 7-day old queens in separate cages was observed in detail in this experiment and some of the results are given in Table VII.

TABLE VII. The results of the encounters of pairs of honey bee queens in perspex cages in the laboratory.

Number of times when victor is the		No victor			
first attacker	second attacker	both damaged	no damage	no aggression	Total
42	10**	4	22	2	80

**Chi-square between the first and second attacker is 19.69 ($P < 0.005$). highly significant.

Three basic behaviour patterns of the queens towards each other were observed; (1) aggressive behaviour, (2) non-aggressive behaviour, and (3) avoidance behaviour.

The aggressive, attacking queen, after a close contact in 48 trials out of 80, immediately held the other queen's wing with her mandibles. At the same time, she bent her abdomen and tried to sting the other, especially between the thorax and abdomen and the anterior part of the abdomen (Figure 2). On 8 occasions the attacking queen held the leg, on two the antenna, and on one occasion the proboscis, of the other queen. If the queens attacked each other at the same time or one could not hold the other's wing then both bit and stung. Damage to both opponents was rare. Usually the first attacker injured or killed her opponent (Table VII). When one queen was killed the stimulus for fighting stopped and the aggressive behaviour of the victorious queen ceased immediately. In all other encounters, after the initial strong aggressiveness, the queens' behaviour slowly changed to non-aggressive or avoidance behaviour.

FIGURE 2. Typical aggression of pair of queens.

Non-aggressive behaviour involved an investigating behaviour in which the queens touched each other with their antennae and front legs. Licking, food soliciting and feeding behaviour were also observed (Figure 3).

FIGURE 3. Food begging of two queens.

Avoidance behaviour was apparent when faeces with a strong penetrating odour were discharged by one or both queens during the first attack. This was observed on 6 occasions and 3 pairs ceased fighting completely.

Discussion

The degree of aggression of one queen towards another queen is related to the differences in their age and condition. In Experiment 1 we did not observe the rather definite observation of Skirkyavichyus, (1965) who stated that similar queens always fight while different queens never do. This may have been because no worker attendants were present in our experiments.

Our Experiment 2 confirmed Velthuis' (1967) findings that the mandibular glands of the queen did not influence the aggressiveness of queens towards each other. He showed the importance of the dermal glands (described by Renner and Baumann, 1964) in the queens' recognition of each other. Perhaps the dermal glands are also responsible for aggression of workers towards queens.

Although queens with previous fighting experience were not significantly more aggressive than inexperienced queens, Experiment 3 did not deny the importance of learning. Perhaps nutrition of the queens or the passage of time during the 24-hour storage after the first fighting experience altered the effect of learning.

Experiment 4 demonstrated that the weight of the queen alone did not determine the result of a fight between queens. The queen which initiated the attack usually destroyed the attacked queen. This could be chance but more likely might be due to the physiological condition of the first attacker. Perhaps a lower threshold for aggression initiated the first attack between queens. Nutrition could increase directly the threshold for aggression, or indirectly affect aggression by the decrease of pheromone production, which probably elicitated aggressive behaviour. The appearance of food-begging behaviour between queens could alter the aggression (Experiment 5). The non-aggressive behaviour between queens was not necessarily rapid adaptation, but could be explained by the lack of stimulus for fighting.

The workers' reflex behaviour is modified by learning, and after being conditioned to one queen at a certain age they may become hostile to any different queen (Szabo, 1972).

The queen's behaviour is instinctively aggressive towards any similar queen. In nature the monogynous colony is maintained in two ways. If in the colony there are

two or more similar queens (in age, condition or attractiveness), the workers can not discriminate between these queens (Szabo, 1972), and in the fight that occurs between them, only one survives (Experiment 6). If the queens are different, (in age, condition and attractiveness) then the workers eliminate the excess queens. In a natural, two-queen colony, one queen is old and hardly functions as queen, as her pheromone production is too low (Butler, 1960) while the other queen, which is her daughter, acts as the normal queen of the colony. These two-queen colonies are always temporary (Ribbands, 1953). Michener (1969) suggested, that selection favoured a single queen condition over a multiple queen condition for many reasons. Higher reproductivity can be attained, it is easier to establish a new colony and caste control is simpler with one queen than with several queens.

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HORMONAL CONTROL OF MALE ACCESSORY GLAND DEVELOPMENT IN THE COCKROACH, *PERIPLANETA AMERICANA* (L.)

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Abstract

The development of the male accessory glands of the American cockroach is described as well as the electrophoretic patterns of their proteins. The effects of hormones on the development of the glands were also examined. Development was shown to be influenced by juvenile hormone and ecdysone. The presence of juvenile hormone inhibited development of the accessory gland. The accessory gland will only develop in a roach that is undergoing metamorphosis. The ecdysone analogue, ecdysterone, cannot by itself initiate accessory gland development.

Introduction

The accessory gland of the American cockroach, *Periplaneta americana* (L.) forms a large mushroom shaped body situated above the last abdominal ganglion. The gland has two distinct groups of tubules. The larger and longer, outer tubules make up the *utriculi majores*, while the shorter, central tubules form the *utriculi minores* (breviores). The accessory gland produces proteinaceous material that is used to form the spermatophore, the vehicle for sperm transfer (Guthrie and Tindall, 1968).

Bodenstein (1943, 1950) examined the metamorphosis of the genital disc of *Drosophila melanogaster* (Meig.), which forms the accessory glands, vas deferens, sperm pump, and the ejaculatory duct. Hadorn (1966) also investigated the effects of hormones on the genital disc of the male *D. melanogaster,* using transplantation technics. Both workers found that discs would undergo development in a metamorphosing insect, but not in adult, male hosts. Discs transplanted into adult males would differentiate when they were removed and reimplanted into metamorphosing hosts. Bodenstein (1943, 1950) found that discs transplanted into adult male hosts would grow and finally differentiate to imaginal completion when under the influence of simultaneously transplanted ring glands. This would occur even when the ring glands were from larvae only 12 hours old.

Our study was undertaken to determine the effects of juvenile hormone, ecdysone, and the ecdysone analogue, ecdysterone, on accessory gland development of the American cockroach.

Materials and Methods

The cockroaches were reared at 25°C with a day length of 12 hours. Animals were supplied with dog chow and water. Instars were selected by weight (Gier, 1947).

Corpora allata were removed using the method of Bodenstein (1953a). To remove the accessory glands, nymphal roaches anaesthetized with CO_2 were restrained ventral side up with pins and the glands were removed with forceps through an opening made between the eighth and the ninth sterna.

Accessory glands for transplantation were removed from roaches and placed in Ludwig's saline (Ludwig *et al.* 1957). The accessory glands were taken from eighth-, ninth-, and tenth-instar nymphs. Within an hour of dissection, the accessory glands were transplanted into the abdomen of the host by means of a glass micropipette.

Corpora allata were handled in the same manner except that they were implanted in the head region. In all transplantation experiments normal animals were anaesthetized and served as controls.

Ecdysterone (Becton, Dickinson and Co.) was dissolved in 2% ethanol in Ludwig's saline to give a final concentration of 10 μg. per μl. Controls received 2% ethanol in saline only.

After all operations, sufficient time was allowed for wound healing and development before the accessory glands were examined as squashes by phase contrast microscopy.

The protein patterns of the accessory glands were examined at various stages of development using the electrophoretic method of Davis (1964). A running gel with a pH of 8.8 was used with a Tris-glycine buffer (16.0 gm. Tris, 9.6 gm. glycine per liter) with a pH of 8.2. Each accessory gland was homogenized in 0.10 ml of saline and 20 l of the homogenate was applied to each tube. Each gel tube was topped with 40% sucrose and run for 55 minutes at 3.5 milliamps per tube in a Shandon disc electrophoresis apparatus. The gels were stained for 15 minutes in 7% Buffalo black in Smithies' solution (methanol-glacial acetic acid-water, 5:1:5) and destained in Smithies' solution till clear.

Results

In the nymphal cockroach, the accessory gland is a small bi-lobed structure without tubules, behind the last abdominal ganglion which innervates it. The gland enlarges during each nymphal instar and after the moult to the tenth stage an increase in size takes place, followed by an increase in tracheation. After forty-five days into the tenth instar, the glands change shape and become triangular (Fig. 1). At this time, cell clusters are seen in the glands. Prior to this, the cells form a sheet. At fifty to fifty-three days, the outlines of the tubules, *utriculi majores* and *minores*, can be seen and by fifty-five days, the tubules are formed internally (Fig. 2). On the fifty-seventh day, the tubules are seen protruding from the surface of the gland. The moult to the adult occurs on the average, on the sixtieth day. One or two days after the moult granules can be seen in the tubules, and the protein secretions continuously fill the tubules during the adult life of the roach (Guthrie and Tindall, 1968; Blaine and Dixon, 1973).

The corpora allata were removed from fifteen newly moulted eighth-instar nymphs. The accessory glands were examined in ten of these after the first moult, and in five, after the second. The first moult in the latter group was nymphal. The degree of development of the accessory gland was related to two factors, the duration of the instar, and the extent of overall development (Table I). Those animals that underwent a nymphal moult had accessory glands showing varying degrees of development, while those that moulted to adults had fully developed though smaller than normal accessory glands. The one nymph that moulted to a semi-adult had a partially developed accessory gland. Tubules could be seen in the gland.

Five animals that were allowed to moult a second time moulted to very small adults with fully developed though smaller accessory glands with fewer tubules than normal. The average time required for these allatectomized eighth-instar animals to moult twice was only slightly less than the time required for normal eighth instars.

The accessory glands of allatectomized ninth-instar nymphs which moulted to adults or semi-adults were as described above for eighth-instar nymphs (Table I).

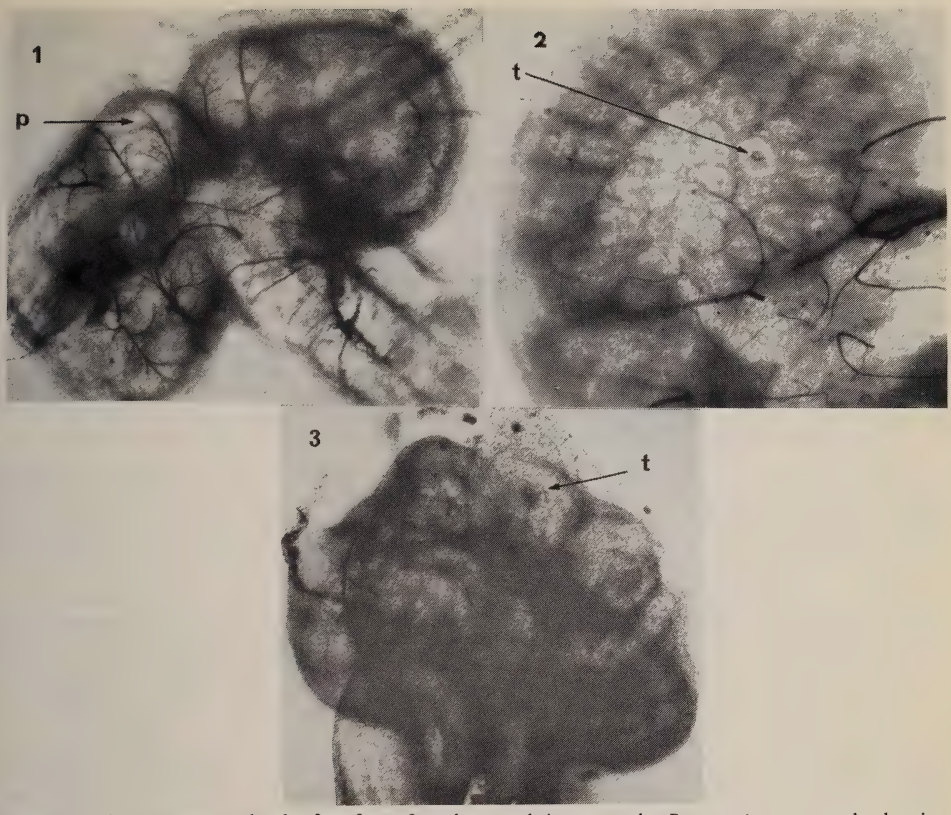

FIGURE 1. The accessory gland of a forty-five day tenth-instar male *P. americana* nymph showing protrusions (p) at anterior end, and triangular shape. 80 x

FIGURE 2. The accessory gland of a fifty-five day tenth-instar male *P. americana* nymph showing tubules (t) developing inside the gland. 80 x

FIGURE 3. The accessory gland of an eighth-instar *P. americana* nymph transplanted into a tenth-instar nymph showing small number of tubules (t) developing. 80 x

TABLE I Development of the accessory glands in nymphal male roaches of *P. americana* (L.) following allatectomy.

Instar	Number of Roaches	Post-operative Days	Condition of Accessory Glands	Moult
8th (one moult)	6	32-36	Increased tracheation only	Nymphal
8th (one moult)	1	55	Increased tracheation, protrusions at anterior, shape triangular	Nymphal
8th (one moult)	1	35	Increased tracheation, shape triangular, tubules forming	Semi-adult
8th (one moult)	2	56,64	Fully developed	Adult
8th (two moults)	5	110-140	Fully developed	Adult
9th	3	38-55	Increased tracheation, cell clusters	Nymphal
9th	4	61-90	Increased tracheation, shape triangular, cell cluster or tubules	Semi-adult
9th	6	65-128	Fully developed	Adult

Among the three having nymphal moults, the amount of gland development was greater than that found among allatectomized eighth-instar roaches that also moulted to nymphs (Table I).

All accessory glands from eighth- and ninth-instar nymphs which were transplanted into normal tenth-instar nymphs or into tenth-instar nymphs which had had their accessory glands removed were partially or fully developed (Table II). The degree of development was related to the length of the postoperative period.

Ninth-instar transplants had a greater capacity for development than did transplanted eighth-instar accessory glands. All ninth-instar transplants, except one, had fully formed tubules containing protein when examined twenty days after the moult. The other transplant and one eighth-instar transplant had only protrusions and cell clusters. Two eighth-instar transplants for which the length of the experimental period was twenty-nine and thirty days respectively, had protrusions with internal tubules (Fig. 3). No protein was present in these tubules.

TABLE II. Development of nymphal male accessory glands of *P. americana* (L.) transplanted into tenth-instar hosts.

	Instar	Number of Roaches	Post-operative Days	Condition of Accessory Glands	Average Weight and Range (mg.)
(1)	8th	7	18-74 + 20*	Development in all, from cell clusters and protrusions to tubules	0.26 0.15-0.45
(2)	9th	8	22-63 + 20*	Development in all, from cell clusters to tubules	0.47 0.05-0.74
(3)	9th	6	10th instar+ 20*	All have developed tubules	1.13 0.41-1.42

*glands left in adult for 20 days after metamorphosis for protein to be synthesized.

(1) and (2) host retained own accessory gland.

(3) host accessory gland removed.

TALBE III. Development of nymphal male accessory glands of *P. americana* (L.) transplanted into adults and nymphs.

Donor	Host	Post-operative Days	Development of Glands
9th	Mature adult	60-65	None
10th	Mature adult	60-65	None
10th	New adult - corpora allata	60	None
10th	9th	Entire 9th instar	None, increase in size

This experiment using ninth-instar accessory glands was repeated with newly emerged tenth-instar hosts which had their accessory glands removed (Table II, No. 3). All of the transplanted glands developed, and the average weight was more than twice that of glands placed in tenth-instar animals which retained their own glands.

In ninth-instar and younger roaches, both the corpora allata and the prothoracic gland are secreting hormone but in the tenth-instar it is thought that only the

prothoracic gland is secreting hormone (Shaaya, 1967). In the adult, only the corpora allata are secreting hormone, as the prothoracic gland has degenerated (Bodenstein, 1953). Thus, in an allatectomized adult neither juvenile hormone nor ecdysone is being produced. Accessory glands were implanted into hosts of various hormonal balance to determine the effect on gland development (Table III). Glands of early tenth-instar roaches when implanted into early ninth-instar roaches showed only an increase in size after the host had undergone the moult. When two or three pairs of corpora allata from nymphs were implanted in tenth-instar roaches no development of the accessory glands was seen after moulting, although the glands had increased in size and in degree of tracheation.

When ninth- and tenth-instar accessory glands were transplanted into normal mature adults or when tenth-instar glands were transplanted into newly metamorphosed, allatectomized adults (Table III) no change was observed in the transplants and no growth was seen.

Partially developed tenth-instar accessory glands were also transplanted into newly metamorphosed, allatectomized adults. Three glands with internal tubules (approximately ten days pre-moult) and five glands with cell clusters (approximately fifteen days pre-moult) were transplanted. None of these glands showed any further development when they were checked fourteen to seventeen days later.

To find out if ecdysterone, the ecdysone analogue, could promote development of accessory glands, tenth-instar glands were transplanted into newly metamorphosed, allatectomized adults. Injections of 15 μ g. of ecdysterone every three days for periods ranging from twelve to forty days (60 to 210 μ g were injected) induced no further glandular development. Tubules were never seen in any of the transplants. The only changes seen were an increase in tracheation and the formation of cell clusters. The formation of protrusions at the gland anterior, resulting in a triangular shape which occurred in normal glands, or in transplanted glands in tenth-instar hosts, and in allatectomized nymphs was not observed in these transplanted glands.

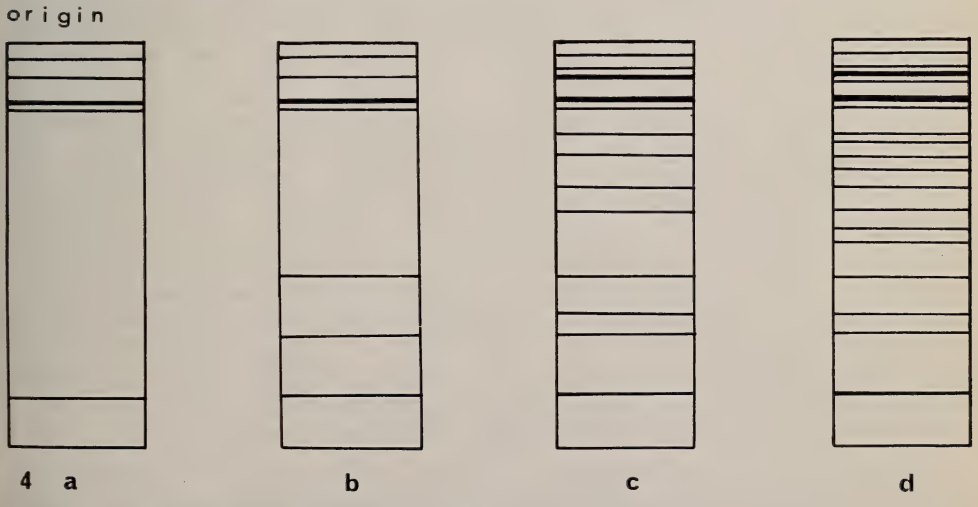

FIGURE 4. Electrophoretic pattern of proteins of male accessory glands of the cockroach, *P. americana* (L.) during development.
4a. Early tenth-instar nymph.
4b. Mid-tenth-instar nymph.
4c. Late tenth-instar nymph.
4d. Newly moulted adult.

The number of proteins found in the accessory glands increased as development proceeded (Fig. 4). The number of bands was constant at 5 during the ninth- and the early part of the tenth-instar (Fig. 4a). During the second half of the tenth instar, a large increase in the number of bands was seen coinciding with observable morphological change in the glands. After fifty-three to fifty-five days, when the tubules are formed, the number of bands had risen to 13 (Fig. 4c). During the final days of the instar, the number of bands increased to 18 (Fig. 4d). As material could be seen in the tubules one or two days after the moult, it was not known whether the additional bands were accessory gland proteins or spermatophore proteins.

Discussion

Metamorphosis is essential to accessory gland development in the cockroach. The accessory gland will not develop in a roach in which juvenile hormone is being secreted. Luscher (1968) suggested that the juvenile hormone is an inhibiting inducer, as it prevents completely the differentiation of imaginal discs in insects such as the Diptera. A similar situation apparently occurs in the undeveloped accessory gland of the roach. With reference to the work of Hadorn (1966), Luscher (1968) suggested that differentiation of the transplanted imaginal discs does not occur in the adult flies because juvenile hormone is being released. However, the absence of juvenile hormone alone is not sufficient to allow differentiation to take place in the cockroach. Tenth-instar accessory glands which would normally undergo differentiation, will not develop when transplanted into adult roaches allatectomized within six hours of moulting. Development would not occur even when the glands remained in the adult for sixty days, which is the average time required for gland development in the tenth instar. Thus, more than the mere absence of juvenile hormone must be required for imaginal differentiation of the glands to occur.

In the last nymphal instar, ecdysone, which has been termed by many a growth and differentiation hormone, is secreted by the prothoracic gland. Thus, ecdysone may be the factor causing imaginal differentiation of the gland in the absence of juvenile hormone. But ecdysterone (an ecdysone analogue) used in these experiments did not cause tenth-instar accessory glands transplanted into allatectomized adult roaches to develop. Over two hundred μ g of ecdysterone were added over a forty-day period.

Ecdysterone can not then be the factor that causes development of the accessory gland during the tenth instar. However, ecdysterone did effect some change in the accessory glands, specifically an increase in tracheation and the formation of cell clusters. Oberlander (1969) has shown that both ecdysone and ecdysterone initiate metamorphosos *in vitro* in wing discs of *Galleria mellonella* (L.). In our experiment, no change in shape, which normally occurs, and which Oberlander observed in *Galleria* was seen. In recent experiments, Oberlander (1972) found that ecdysterone inhibited the effect of ecdysone and he concluded that ecdysterone may have different functions in development. Moriyama *et al.* (1970) and King and Siddall (1969) have shown that alpha ecdysone injected into or ingested by *Calliphora erythrocephala* (Meig.) or *Bombyx mori* L. larva is rapidly converted to beta ecdysone (ecdysterone). Thus ecdysone and ecdysterone induced changes may be sequential.

During the ninth and early tenth instar, only five proteins were found in an accessory gland homogenate. The number of bands increased to seven by the middle of the tenth instar and to thirteen late in the instar. This means that some development occurred prior to the middle of the instar. According to Shaaya (1967), ecdysone is not released until the middle of the instar, and juvenile hormone is not secreted during the tenth instar. The development of the accessory gland at the beginning of the tenth instar is not then due to either of these hormones. There could

be some other factor, induced by the lack of juvenile hormone, and/or of ecdysone which initiates development.

Bodenstein (1943, 1953b) has shown that imaginal discs of *D. melanogaster* (Meig.) and the external genitalia of *P. americana* (L.) must undergo a certain amount of larval or nymphal growth and development which renders them competent for adult development. We have shown that both eighth- and ninth-instar accessory glands were competent to undergo imaginal differentiation. This development could occur precociously, but the number of tubules formed would be smaller than normal.

However, if the corpora allata are removed from eighth- or ninth-instar nymphs, precocious development of the accessory glands occurs in only some of the roaches, and in a smaller percentage of the eighth-instar roaches. Also development stops almost immediately in glands transplanted into adults. When eighth- and ninth-instar glands are placed in a tenth-instar host for only the last thirty days of the instar, complete development occurs. Transplanted ninth-instar glands grew to twice normal size in tenth-instar hosts which had had their accessory glands extirpated. Perhaps essential proteins are synthesized in the tenth instar which are necessary for the differentiation process. Tubule formation does coincide with an increase in protein bands in the electropherograms.

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IRRADIATION OF THE FEMALE FACE FLY, *MUSCA AUTUMNALIS* DEGEER[1], PARASITIZED BY THE NEMATODE, *HETEROTYLENCHUS AUTUMNALIS* NICKLE[2]

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Abstract

The release of irradiated female face flies, parasitized with *H. autumnalis* DeGeer, was considered as a supplement to the release of sterile male flies. Previous research indicated that 2.5 krad of gamma-radiation given to 5-day old face fly pupae produced complete sterility in both sexes. Parasitized females, irradiated with doses of 1.0 krad and 2.5 krad produced F_1 and F_2 progeny with high levels of parasitism, indicating the nematodes were not sterilized by these doses of irradiation.

* * * * * *

Introduction

The face fly, *Musca autumnalis* DeGeer, is an important pest of cattle and horses as an irritant and a vector of eye disease. Insecticides give variable and often unsatisfactory control of this pest. Consequently, recent research emphasis has been concerned with the development of biological or cultural control techniques that might be used against the face fly. In our laboratory, investigations have included a search for techniques to increase the natural population of *Heterotylenchus autumnalis* Nickle, a nematode parasite of the face fly, and an examination of the effects of gamma irradiation on the face fly.

The nematode *H. autumnalis* was first described by Stoffolano and Nickle (1966) and has since been found in face flies throughout North America. The incidence of parasitism is variable; 21% in Nebraska (Jones and Perdue, 1967); 6% in New England (Stoffolano, 1968); 30-40% in Missouri (Thomas and Puttler, 1970, and Thomas *et al.* 1972), and 3% in Ontario in 1970-71 (Wright, 1972). Detailed accounts of the life cycle of this nematode have been presented by Nickle (1967), Treece and Miller (1968) and Stoffolano (1970). Parasitized female face flies are "sterilized" when thousands of infective nematodes invade the flies' ovaries. The nematodes complete their development in the ovaries and inhibit all normal egg production. They are transmitted by mock oviposition to fresh cattle droppings where they mate and the infective female invades newly hatched face fly larvae. This nematode has great potential as an effective biological control agent if techniques can be developed to increase its rate of infectivity in the field.

The examination of the effects of gamma irradiation on the face fly has shown that the females fail to produce eggs at 1.5 krad and above, while the males, irradiated at 2.5 krad, are completely sterile but as competitive as normal males (Gregory, 1973). Although these tests indicate the face fly can be easily sterilized, it is apparent that a "sterile-male release" type program would have little effect in regulating the large face fly populations that occur throughout much of North

[1]Diptera: Muscidae.

[2]Nematoda: Sphaerulariidae.

[3]Graduate student and Assistant Professor respectively, University of Guelph. Material taken from part of author's Ph.D. thesis.

America. However, this technique does lend itself to an incorporation with other potential control techniques. One such use of combined techniques is a release of irradiated nematode parasitized flies. The benefits of such a release would be that the irradiated males would compete with wild males for wild females, while the "sterile" females would compete for wild males and at least a certain percentage of these females would contribute infective nematodes to the natural habitat, thus increasing nematode infection in the wild population. The major question concerning such a program was the effect of the irradiation on the nematodes. This paper presents the results of a study to investigate the effects of irradiation on the nematode parasitized flies and the feasibility of such a combined approach for reduction of face fly populations.

Materials and Methods

Nematodes were obtained from native female face flies and used to infect a stock colony of USDA face flies following the method of Stoffolano (1970 and 1973). This nematode parasitized colony was maintained in an insectary at a temperature of 25.5 C, R.H. of 50-70%, and a 16 hour photo-phase. A diet of citrated blood and diastatic malt syrup[1] solution (3 parts water: 1 part diastatic malt syrup) was supplied once daily on cellucotton pads, while cups of water were available at all times within the cages. Fresh cow manure was offered to the flies for oviposition at 14 days of age. After 24 hours the oviposition manure was divided and placed on fresh manure in larger containers, which were then placed over sand, which served as the pupation site.

Two dosages of irradiation, 1.0 krad and 2.5 krad, were used in these studies. Irradiation was conducted on 5-day old parasitized pupae in the Gammacell 220[2]. After irradiation, pupae were placed in emergence containers until adult eclosion and separated by sex within 6 hours of eclosion. In the first three tests (R1, R2, and R3) 1.0 krad dose was used, as previous work had shown, this dose produced a 98% sterility in males, and that females so irradiated produced few eggs (Gregory, 1973). In the other test (R4) a dose of 2.5 krad was used.

Experimental Procedures and Results

In experiments R1 and R2, untreated and irradiated flies from the nematode parasitized colony and flies from a USDA colony were combined in two cages (Cage 1 and Cage 2). Cage 1 contained 200 untreated females, and Cage 2 contained 200 irradiated females (F_1 adults), all from parasitized pupae. To ensure adequate egg production, 100 normal USDA males and 100 normal USDA females were added to each cage. Oviposition media was offered for 1 hour on the 14th day after emergence. After oviposition, all females were dissected (under 0.9% Ringer's Solution) to determine the level of parasitism of F_1 adults. The eggs produced by the F_1 adjults were handled according to normal rearing procedures with the resulting adults being termed F_2 adults. These adults were kept 14 days, at which time they were dissected to determine their level of parasitism. Results of these two experiments (R1 and R2) are shown in Table I

The level of parasitism increased from 6.3% and 4.01% in the parental stock (P) to 21.43% and 28.0% in the F_2 adults in the untreated females. The increase in parasitism was more dramatic with irradiated females increasing to 41.22% and 75.00% in the F_2 adults. These results indicated either a more competitive nematode in the irradiated flies or the influence of a greater number of egg-producing females in Cage 1 at the F_1 generation.

[1]Panamalt, Type P.M. Regular. Standard Brands Ltd., Montreal.

[2]Atomic Energy of Canada, Ottawa.

TABLE I. Level of parasitism of female face flies with *H. autumnalis*, through two generations after irradiation of 5-day old parasitized pupae (P) at 1.0 and 2.5 krad.

	% Nematode Parasitism of:				
	Parental	Irradiated Flies		Untreated Flies	
Experiment	Colony (P)	F_1	F_2	F_1	F_2
R1	6.3	6.0	41.22	8.5	21.43
R2	4.01	5.0	75.00	4.0	28.00
R3	28.72	56.0	—	49.0	—
R4	25.00	—	—	—	—

In order to investigate the possibility of a more competitive nematode, a third experiment (R3) using 1.0 krad and a fourth experiment (R4) at 2.5 krad were performed using a slightly different experimental design. The difference was the addition of 150 irradiated USDA females to Cage 1 and 150 normal USDA females to Cage 2. This design provided the same total number of flies in both cages and approximately the same number of egg-producing females, depending on the level of parasitism of the female face flies. As in the previous tests, females from the F_1 and F_2 generations were dissected at 14 days of age to provide the level of parasitism and the results tabulated in Table I.

In the third experiment (R3) levels of parasitism in parental and F_1 flies were much higher than those found in experiments R1 and R2. Consequently, only a few pupae survived and these had to be preserved to maintain the stock colony. These results indicated that the increased levels of parasitism in the irradiated flies in experiments R1 and R2 was not due to a more competitive nematode.

Infection by an *Entomophthora* species complicated the results of experiment R4. This fungus only attacked irradiated flies. Survival of F_1 adults was poor, and by day 14, only one parasitized female survived. No infection of F_2 adults occurred. Untreated F_1 adults were not carried through to the F_2 generation. Dissection of F_1 females showed invasion of the ovaries by the nematodes in both the irradiated and untreated females. This indicated that parasitization of F_2 adults would probably have occurred had not the *Entomophthora* infection interfered. The fungus infection was so overwhelming that it made determination of parasitism in females almost impossible.

Although no critical estimate was made of the number of infective nematodes present in the hemocoel or ovaries of untreated or irradiated females at each level of irradiation, there was no obvious difference between the two groups of females. This indicated that the nematodes were not being sterilized at the levels of irradiation used. Percentage of adult eclosion from irradiated and untreated pupae was similar. At 1.0 krad, 90.43% of adults emerged while at 2.5 krad 92.28% of adults emerged. The corresponding eclosions for untreated adults was 89.43% and 91.37% respectively.

Discussion

Heterotylenchus autumnalis can survive irradiation doses of 1.0 and 2.5 krad in the 5-day old face fly pupae. The nematode is not sterilized at these levels. The competitiveness of the irradiated, parasitized adult flies is unknown. If they are competitive, the release of irradiated, parasitized face flies might prove highly effective for control of this species.

Some difficulty was encountered in building up a stock of parasitized flies while maintaining a high level of parasitism without affecting larval survival or pupal

formation. Part of this difficulty may be due to larval mortality caused by the nematode. Branch and Nicholas (1970) reported that as few as two nematode larvae of the *Heterotylenchus* species may kill larvae of the Australian bushfly, *Musca vetustissima* Walker. However, by careful mixing of parasitized flies with non-parasitized flies, it is possible to consistently produce a generation of flies with a 25-30% level of parasitism. Further refining of this technique, with adequate infusion of non-parasitized flies or by addition of non-parasitized eggs to eggs and nematodes collected from a nematode-parasitized colony, should produce a generation of flies with a level of parasitism of 75% or higher. A level of parasitism this high used in a sterile-male release would certainly be advantageous over a release of sterile insects alone.

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IN MEMORIUM

William Robin Thompson 1887-1972

An obituary written by J. Antony Downes was published in the Bulletin, Entom. Soc. of Canada 4(3): 38-40, 1972. In 4(4) of the same publication an article entitled Robin Thompson—a Kindred Spirit, prepared by Professor A. W. Baker, appeared.

David Edgar Gray 1913-1972

In the Bulletin 5(1): 11, 1973 an obituary prepared by Douglas C. Eidt was published.

We miss and we remember these former members, colleagues and good friends.

Carol Grace (Quigley) Baker

Mrs. A. W. Baker's sudden death as the result of a car accident on July 5, 1973 caused widespread sorrow among her many friends.

All of the older members of our Society will always remember the warm hospitality of the Baker home on the many occasions when meetings were held at Guelph. These evenings were spontaneous, happy affairs which lasted until late and seemed so short. Everyone present felt welcome and wanted. Nothing ever ruffled Grace's serenity, no matter how large the crowd nor how short the time for preparation. We miss her.

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I. REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

INSECTS OF THE SEASON IN ONTARIO 1973 RELATED TO FRUIT, VEGETABLES, FIELD CROPS AND ORNAMENTALS

F. L. McEwen

Department of Environmental Biology, University of Guelph

Abstract

Normal to less than normal populations of pest insects were present in Ontario in most cases. There were some exceptions. These are noted below.

* * * * * *

Fruit

The codling moth, *Laspeyresia pomonella* (L.) was more difficult to control this year especially in the eastern part of Ontario. For some reason, the adult flight of the insect was prolonged much longer than normal. San Jose scale, *Quadraspidiotus perniciosus* (Comstock), which has not been significant in Ontario for many years appeared this year in a few commercial orchards. There is no ready explanation for the reappearance of this pest.

Vegetables

This was the year of the cabbage looper, *Trichoplusia ni* (Hübner). The insect appeared in Ontario in late June and had two very heavy generations. It has now become tolerant to many of the insecticides recommended for its control and vegetable growers had great difficulty in preventing extensive crop damage on cole crops and, to a lesser extent, on crops such as tomatoes and potatoes. Flea beetles (various species) were particularly abundant this year on cole crops, potatoes and tomatoes.

Field Crops

For the first time in Ontario, the cereal leaf beetle, *Oulema melanopus* (L.) was present in some areas in sufficient numbers to cause economic damage. A small acreage was treated for this pest in 1973. Armyworms, *Pseudaletia unipuncta* (Hawarth), were present in damaging numbers in a small area in Ontario in 1973.

Miscellaneous Pests

Black flies and mosquitoes, especially the latter, were particularly troublesome in 1973 in many areas of Ontario.

Ornamental Plants

Cedar Leaf Miners, *Argyresthia* and *Pulicalvaria* species, which occur in damaging numbers in some years were quite destructive in 1973. Many of the

swamp cedars in central Ontario were severely damaged early in the season. The hairy chinch bug, *Blissus leucopterus hirtus* Montandon, was again present in 1973 in some areas of Ontario and caused significant damage to lawns and golf courses. While damage has been reported for the past several years in a number of Ontario communities, e.g., London, Guelph, Kitchener, Sudbury, there is little indication that the pest is becoming more established or more numerous. Damage is still very much at a local level.

INSECTS AND OTHER ARTHROPODS OF IMPORTANCE DURING 1973 IN HOUSES, WAREHOUSES AND ON LIVESTOCK IN ONTARIO

W. C. Allan

Department of Environmental Biology, University of Guelph

Abstract

A resume of the occurrence in Ontario during 1973 of certain species of insects and other arthropods in houses, warehouses and on livestock.

* * * * * *

Houses

Cluster flies, *Pollenia rudis* (F.) were outstanding pests in homes and other buildings. Reports of large populations were recorded during the spring and late fall seasons. Carpenter ants, *Camponotus pennsylvanicus* (De Geer) were found frequently in houses in widespread areas of Ontario. In many instances these ants were traced to old tree stumps.

Many instances of large populations of fleas, *Ctenocephalides* spp. were reported.

There was a substantial increase in the number of cases reported of infestations by cockroaches, particularly *Blattella germanica* (L.). The majority of these reports came from apartment buildings and condominiums.

Silverfish, *Lepisma saccharina* L. were numerous in many areas of Ontario during the past year and reports were received regarding this insect infesting homes and apartments over a widespread area. Millipedes, *Narcus* spp. while not as plentiful as during the past two years, were found in large numbers on driveways and in basements of many homes.

Carpet beetles, particularly the larvae of *Attagenus* and *Anthrenus* spp. were frequently found in houses but no significant degree of damage to fabrics could be attributed to these beetles. Larder beetles, *Dermestes lardarius* L. were reported many times in both larval and adult stages. In all cases populations of this beetle were associated with pet food or bird seed.

Grain beetles, *Oryzaephilus* spp. were reported with much lesser frequency than in previous years.

Warehouses

Indian meal moth, *Plodia interpunctella* (Hbn.) was the most common insect found in warehouses and grain storage areas. Confused flour beetle, *Tribolium confusum* duV. was found to be present in many warehouses in the province.

Livestock

Face flies, *Musca autumnalis,* De Geer, were much more numerous during 1973 than they have been for some years. Populations were high in many areas and outbreaks of pink eye were observed in pasturing cattle. Horn flies, *Haematobia irritans* (L.) were fairly widespread but no serious infestations were noted. Mosquitoes, *Aedes* spp., and black flies, *Simulium* spp. were very numerous in some areas and caused quite a bit of discomfort to animals on pasture. This was true also of biting flies, *Tabanus* spp., especially on horses. House flies, *Musca domestica* L. were frequently reported as being numerous in pens and stables and in many cases constituted a problem to stabled cattle.

NOTEWORTHY FOREST INSECTS IN ONTARIO IN 1973

A. H. Rose

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Sault Ste. Marie, Ontario P6A 5M7

Abstract

This is a resumé of the 1973 survey records of forest insects that for a variety of reasons are important or noteworthy. Also included are records of other insects.

* * * * * *

Indigenous Insects

Coniferous Trees

This is the seventh year that the spruce budworm, *Choristoneura fumiferana* (Clemens), has dominated the forest insect scene in Ontario. It caused damage to approximately 18.5 million acres (Sippell *et al.* 1973), a decline of 0.8 million acres from 1972. As a result of chemical control operations carried out by the Ontario Ministry of Natural Resources on 77,000 acres in northwestern Ontario the amount of defoliation there was greatly reduced and only small pockets of infestation totalling 10,000 acres remain. The collapse of budworm populations northeast of Chapleau caused by a severe spring snowstorm in 1972 was evident in 1973, but damage elsewhere in the broad band of infestation covering 12.5 million acres extending from Lake Superior to the Quebec border was mainly severe. In southeastern Ontario, there was only a small increase in area affected for a total of 6 million acres. However, in both northeastern and southeastern Ontario egg mass numbers in the infested areas have shown large increases over 1972. Tree mortality and top kill are becoming more prevalent in both these infestations.

Once again jack pine budworm, *Choristoneura pinus pinus* Freeman, infestations were confined to the vicinity of Britt, north of Parry Sound, with damage occurring in an area of 70 square miles.

Although there was a decline in the extent and intensity of damage by the complex of cedar leaf miners, *Argyresthia aureoargentella* Brower, *A. canadensis* Freeman, *A. thuiella* (Packard) and *Pulicalvaria thujaella* Kearfott in southern Ontario, pockets of noticeable damage persisted in the vicinity of Smiths Falls, Kaladar, Guelph, Stratford and St. Williams.

Native pine sawflies were present at low population levels except for the red headed pine sawfly, *Neodiprion lecontei* (Fitch), and the white pine sawfly, *Neodiprion pinetum* (Norton), which caused appreciable defoliation near North Bay and Parry Sound, respectively.

Across much of northern Ontario population levels of the larch sawfly, *Pristiphora erichsonii* (Hartig), were very low.

An unusual infestation of the scolytid beetle, *Myeloborus ramiperda* Swaine, killed many shoots on mature white pine north of Kingston.

High populations of the pine leaf chermid, *Pineus pinifoliae* (Fitch), caused widespread white pine shoot mortality west of Pembroke.

Broad-leaved Trees

Hardwood defoliators were especially prevalent in northern Ontario. The large aspen tortrix, *Choristoneura conflictana* (Walker), caused widespread defoliation of aspen within an area of 37,500 square miles. This represents a reduction by one quarter in affected area, mostly north and east of Lake Superior where a massive infestation has broken up into smaller ones varying in size from a few hundred acres to 1,500 square miles (Sippell *et al.* 1973). However, a large increase in area infested occurred north and west of Thunder Bay and near Red Lake. In addition, a number of new small infestations developed south of Mattawa and on the Bruce Peninsula.

Developing infestations of the forest tent caterpillar, *Malacosoma disstria* Hübner, reported in 1972 expanded and new infestations were reported. Noteworthy infestations were located as follows: near Ear Falls and between Dryden and Vermilion Bay in northwestern Ontario, between Beardmore and Geraldton north of Lake Superior, near the junction of highways 11 and 631, east of Kapuskasing on Highway 11, within a radius of 45 miles of Sudbury, near New Liskeard, northwest of Lake Nipissing, near North Bay, and north of Kaladar in southeastern Ontario. Light trap catches of adults suggest that widespread population increases had occurred. Later in the season, the aspen blotch miner, *Lithocolletis ontario* Freeman, caused heavy leaf damage at numerous locations across the north.

Most birch in northwestern Ontario lost their leaves early as a result of heavy feeding by the birch leaf skeletonizer, *Bucculatrix canadensisella* Chambers, but other areas southeast of Gogama and in a broad band from Espanola to the Quebec border were also affected with the total area involved being about 90,000 square miles.

The oak leaftier, *Croesia semipurpurana* Kearfott, a perennial early pest on red oak foliage, declined in numbers except in southeastern Ontario, but small pockets of midsummer defoliation by the orangestriped oakworm, *Anisota finlaysoni* Riotte, persisted along the lower lakes.

Fall webworm, *Hyphantria cunea* (Drury), populations which have been low since the late 1950's showed signs of resurgence and the unsightly tents were a common occurrence at numerous locations throughout the Province.

Basswood looper, *Erannis tiliaria* (Harris), larvae were found commonly in small numbers in a broad band extending from Lake Superior to Pembroke, probably indicating a future outbreak of this hardwood defoliator.

Introduced Insects

Coniferous Trees

Population levels of the European pine sawfly, *Neodiprion sertifer* (Geoffroy), were generally down in southern Ontario. However, in recently invaded locations outside the main body of infestation in the Ottawa Green Belt, in plantations on Manitoulin Island, and east of Sault Ste. Marie, populations are building up and spreading. In addition, infestations were found on recently planted ornamental stock west of Bracebridge and near Pembroke.

The introduced pine sawfly, *Diprion similis* (Hartig), extended its range to southwest of Bracebridge.

An unusually severe infestation of the European pine shoot moth, *Rhyacionia buoliana* (Schiffermüller), damaged 80 per cent of all bud clusters in a red pine planting north of Owen Sound.

Broad-leaved Trees

For many years the northern limit, roughly a line from Midland to Cornwall, of the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), has remained relatively constant. Populations discovered north of this line in Sault Ste. Marie and Ottawa apparently have not survived. Brood galleries of this species were found near Denbigh, southwest of Renfrew, some 40 miles to the north of its known range. Its ability to survive there will be closely watched.

The known range of a birch leaf miner, *Messa nana* Klug, was extended 30 miles east of its previous limit by a collection at Kemptville.

The mountain ash sawfly, *Pristiphora geniculata* (Hartig), extended its northern limit by 45 miles to Smoky Falls on Highway 867 north of Kapuskasing, and its western limit by 50 miles to Northern Light Lake, west of Thunder Bay.

Fall surveys by the Plant Protection Division of the Canada Department of Agriculture for eggs of the gypsy moth, *Porthetria dispar* (Linnaeus), revealed its presence throughout Glengarry County, in the vicinity of Cornwall, near Kingston, as well as on Wolfe and Howe islands.

Miscellaneous Insects

Interesting distribution records were obtained for three insects. The weevil, *Barypeithes pellucidus* Boheman, a nursery pest in Europe, massively invaded a home in a wooded area north of Sault Ste. Marie. What the insect was feeding upon was not ascertained.

The corn leaf aphid, *Rhopalosiphum maidis* (Fitch), was found in immense numbers in the second week of August within a radius of 40 miles of Sault Ste. Marie and far removed from any large corn-growing area, and the southern armyworm, *Spodoptera frugiperda* (J. E. Smith), another migrant, laid large numbers of eggs on many ornamental trees as well as on other material in the city in early September.

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II. SUBMITTED PAPERS

A LOOK TO THE FUTURE OF APPLIED ENTOMOLOGY[1]

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This year the City of Kingston celebrates 300 years of existence. By North American standards, this is a long history and it is appropriate that the city look back with pride at its accomplishments and look forward with anticipation of even better years ahead. By Kingston standards, the Entomological Society of Ontario is only a "pup", a mere 110 years old, but with its meeting in Kingston during the city's 300th year, it is especially appropriate that this society look at its profession in various areas and assess what the future may hold.

In speaking to the subject of applied entomology and its future, I can assure you that my crystal ball leaves much to be desired. The subject could be approached through an historical review of past events and a projection of where a continuation of the same would lead us. I rejected that route for two reasons:

1. Our history would show both high and low periods in applied entomology during the past 110 years, and to project this to the future would tell us little.
2. The population changes of the future will be so dramatic that pest problems will be viewed in an entirely different light than have those of the past.

How, then, can I approach the topic? I should first point out that one could characterize applied entomology in 1973 with relative ease. Similarly, it would not be too difficult to characterize entomology or applied entomology in 1974 or 1975. However, even such shortrange characterizations tend to be subjective. As one moves beyond the immediate to characterize the future of a profession, the subjectivity becomes even more pronounced. Perhaps by electing to preview the parameters that may affect applied entomology, one can remove some of this subjectiveness.

As I view applied entomology it is a profession that responds to the needs of people. Its future, therefore, depends on how events of the future focus insect problems on people. I have elected, therefore, to look at some trends for the future that will have major impact on the role of the applied entomologist. In doing this, I put no time frame on the future because the trends I cite will have different time frames in different geographic areas. What, then, are some developments that will greatly affect our profession?

1. Increased Need for Food

The increase in world populations during the past two centuries and especially during the last 50 years have been one of the truly alarming developments. We have moved from a population of slightly over one billion in 1800 to three and

[1]Presented at the 110th Annual Meeting, Entomological Society of Ontario, Kingston, Ontario, Oct. 31-Nov. 2, 1973.

one-half billion today. Projections for the population from here on out vary drastically among experts making the predictions.

While the rate of population growth in many of the developed countries is in the order of 2½ per cent per year, population growth rates in other areas are far higher. There is fair agreement that our population will double by the year 2000 and if this rate of increase continues, the world will contain one hundred billion people in 200 years. Can we feed them?

Our technology has not yet discovered a means of producing food other than through photosynthesis. deWit (1967) calculated the maximum food production of the world based on his interpretation of a reasonable photosynthetic potential on all of our arable land. He calcuated that the world was capable of producing food to feed one thousand billion people, provided nobody lived here. However, when he subtracted from his land base the amount of living space rerequired for people (and he calculated this on the basis of the population presently existing in the megalopolis that extends from Boston to Washington), the number of people that the earth could provide living space for and feed was reduced to one hundred and forty-six billion. He reasoned, however, that the population area he chose was too dense and if he provided the future population twice as much living space, then the maximum number of people that the earth could provide living accommodation for and feed is about eighty billion—less than that projected for 200 years from now. The inference from this, of course, is that in the future, some day, the demand for food for human consumption will be so great that we cannot permit significant loss due to insects.

2. **Increased Need for Protection from Biting Insects**

In addition to preventing insects from destroying our food supply, the applied entomologist will be called upon to ensure the comfort and health of people. This increased population will require spaces for living and for recreation that are now heavily infested with mosquitoes, biting flies and other pests that cause discomfort and transmit disease pathogens. There are many additional sections in Canada, for instance, that would be pleasant to live in were it not for our problems with biting flies.

Think for a moment of the problems that this will present to the applied entomologist. As most of you will know, the insecticide, DDT, was very effective for mosquito and black fly control. Using only a little knowledge and a lot of DDT we demonstrated in Canada and elsewhere that our problems with mosquitoes and biting flies could be overcome. Most of you also will be aware that this kind of usage of DDT was very destructive to other parts of our environment and because of this, DDT can no longer be used. Thus we have now gotten rid of DDT, but we have reinstated the biting fly problem and if 1973 can be used as an example, with a new vigour.

I should also point out that in areas of the world where mosquito control is essential because of health reasons, some environmental damage from DDT has had to be accepted, because the alternative, in terms of human suffering, could not be tolerated.

We must control biting flies if we are to make many areas of our country pleasant places in which to live. Perhaps I should expand a bit on this point as it relates to applied entomology on the local scene. In 1973, the Ministry of the Environment and the Ministry of Natural Resources in Ontario teamed up to present recommendations on controlling mosquitoes and black flies in Ontario. In the light of what we know, the recommendations are as reasonable as can be made. But to apply these recommendations in Ontario or elsewhere, the input from

applied entomologists must be tremendous. The report points out that, within reasonable limits, the larger the area in which mosquito control or black fly control is attempted, the more satisfactory is likely to be the results. Thus we are talking about control on a community basis. Now, before any control is attempted, what do we need?

1. We need a complete survey of the area to find out where the breeding sites are, what's breeding there, and to estimate the volumes of water associated with these breeding sites.

2. We need to know the life cycle of the various species involved and what factors will contribute to high survival or high mortality in their immature stages.

With this kind of information as a starting point, you can then approach control from several aspects. One, of course, is to remove breeding sites by drainage, etc., but there is a very definite limit to the extent to which this can be done. The second approach is to use insecticides and with the insecticides that are likely to be available for use in aquatic areas, selectivity in action and short duration of persistence will be required. The kind of decisions that must be made with respect to this kind of program cannot be made by a layman. Much of the work of the survey, the supervision of any control methods that are involved and the analysis of the control achieved, will be the responsibility of an applied entomologist. If you think for a moment of the many areas in Ontario where people will live as the population increases, it is easy to see that the need for applied entomologists in the area of biting flies will become very great indeed.

Of course one can always hope for a panacea, a DDT without the adverse side effects of DDT. An insect hormone that will be specific to biting flies. A disease that will wipe out all of the pests with which we are concerned. Or a sudden immunity on the part of people to irritation by mosquitoes and black flies. Perhaps I have given up too soon, but I see no panaceas, only hard work and persistence by dedicated applied entomologists using all of the tools of the trade.

What I have said thus far is essentially that in the future there will be a lot more people in the world, that these people will need a lot more food; that we will not be able to share our food supply with insects. And that in addition these people will want to be protected from nuisance insects. We must now make an assumption that people, when they have recognized these needs, will recognize the means to meet the needs, that is, society will be prepared to support the number of applied entomologists required to ensure pest control. Many of us might argue that this is not a reasonable expectation and that, in fact, society does not do this today. While there is some element of truth in this, I believe we must accept that our statements about not having enough applied entomologists, or not having enough entomologists of any type, for that matter, has a ring of subjectivity. All of us would agree that we could do a better job in pest control if we had more manpower. But viewed in the context of other social priorities, perhaps that need is not now our number one concern. We do have an adequate food supply and most of us get through the season without any serious adverse effects from nuisance pests. I believe that when these two observations can no longer be made, society will move to support the force of applied entomology necessary to protect its interests.

3. **Pest Problems Will Increase**

The third generalization I would make about the future is that pest problems will increase. I have not attempted to produce the detailed inventory that would be necessary to prove that we have more insect pests today than we had, say one

hundred years ago. It is my impression that this is the case, or, that if it is not the case, then the pests that have been here all of that period of time are causing us more problems. Certainly it is true that with modern transportation methods, pests become established in new regions rather readily and with changes in practices, particularly agricultural practices such as monoculture, some pests find these situations ideal for their survival and hence the effect of their presence becomes more noted. Certainly it is a principle in ecology that diversity contributes to stability of an ecosystem. In our agro-ecosystems, we have purposely moved away from diversity and practice the kind of community instability that permits rapid population increase in a species adapted to this new habitat. As we look toward the future, I see monoculture becoming the "norm" and diversity in culture becoming rare, indeed. Thus the applied entomologist may have to compete with insects in a fight in which the balance is tipped heavily in favour of the insects because of the ideal situations provided for their survival.

4. **The Entomologist Will Have New Tools**

What tools will the entomologist use? It is easy nowadays to get tied up in the jargon of pest control and lose sight of the concepts. I said I would not discuss history but a bit is pertinent here. When most of us took our first courses in applied entomology, we were required to learn certain principles. We were told that there were cultural methods of control, that there were physical methods of control, that we could use resistant plant species, that there were legislative controls with respect to quarantines, and that there were chemicals for insect control. We were told that all of these played a significant role and that all should be considered in deciding insect control practices. And certainly all of us were told that it was absolutely essential that we knew the biology and life cycles of the insects we dealt with. If I may emphasize this point. In 1896, Mr. C. H. Fernald, in his presidential address to the 8th Annual Meeting of the Association of Economic Entomologists made the following comments:

"I cannot rid myself of the conviction that in economic entomology, God helps those most who most help themselves. Those who make themselves most conversant with His laws as exhibited in the life and habit of the insects they have to deal with as well as the climatic and other conditions which affect them. In fact, the whole environment, and make the best possible use of this knowledge in their attempts to destroy insects or hold them in check."

In recent years this concept has re-emerged with new vigour under the title of "Integrated Control". The re-emergence is timely because we went through a period about twenty-five years ago when we had insecticides that were so effective that good insect control was obtainable without knowing much about the life cycle of the pest involved.

Recently, the President-elect of the Entomological Society of Canada, Dr. C. R. Harris, spoke to the C.A.C.A. convention in Toronto and emphasized this point. If I may quote from his comments: "In retrospect, this period in the late 1940's and the early 1950's marks the decline of economic entomology in Canada. Insect control was so simple that an economic entomologist no longer needed more than a superficial knowledge of the biology of the pest. These chemicals were so easy to apply and cheap, that other effective, but more costly or time-consuming methods of pest control, such as crop rotation, were phased out. Many economic entomologists devoted their time to screening new chemicals year after year and were often referred to by their more "pure" colleagues as "squirt and peek" or "spoon and shovel" scientists."

I referred to DDT earlier with respect to biting fly control. This material was equally as spectacular in the control of a great many of our pests of food crops. The concept of integrated control now brings us back to a realization that insect

control is not something you buy in a can but rather it must come through a carefully designed program that uses all the information that we can find that deals with a particular biological system. As most of you will know the new jargon is "Pest Management" and embodied in this term is something more than just pest control. It includes the concept that an insect species is something which may be manipulated at any time during its 12-month cycle and should be followed throughout the year, not just when it reaches a point at which overt control measures become necessary to effect crop protection. Integrated control is a means by which pest management may be achieved. And I believe it is a means that will be used for a great many years to come. I mentioned earlier that integrated control was nothing new. It is good applied entomology. What is new, however, is the vastly increased resources that we can integrate in our efforts in pest control. To those approaches of control that were available to us many years ago, we can now add such things as the use of insect pathogens, genetic manipulations through the sterile male technique or other approaches, hormones that disrupt the normal life cycle, sex attractants which provide us lures of tremendous potency and specificity, and such things as anti-feeding compounds to name but a few.

What is also new is the computer. Here we have the mathematical genius that can, in the hands of a skilled biologist, pull together that data on the insect's relationship to its environment and assist us in sorting out the parameters that describe its success. Each of us who has been involved in applied entomology has worked with models and identified some of the components that affect biological systems. But until now, we have had to rely largely upon the capacity of a rather small brain. The computer changes all that. It permits modelling on a grand scale and with the proper biological data, it should be possible to go a long way toward predicting pest problems and predicting how the various management practices available to the applied entomologist may contribute to the solution of these problems.

And finally the entomologist of the future will have available to him a wide range of chemical insecticides. Some will be broad spectrum, some rather specific, some highly toxic, some much less so. I suspect that even one hundred years from now these chemical insecticides will still be the basis for control of insect populations that have gotten out of hand. But I would venture to predict that as our population increases, and insect control procedures become more sophisticated, most of the insecticides will be available only on a prescription basis. And I would further suspect that the applied entomologist will not only be the one who recommends an insect control program or pest management program, but also will be the one responsible for carrying it out. I suspect that there will be a clearly-defined profession of applied entomology just as there is today a medical profession or a profession dealing in veterinary medicine. Our requirements in pest management will be such that they cannot be left to the layman to effect.

In conclusion I see a very demanding and challenging future for applied entomology and the applied entomologist. I see a profession providing an essential service to society. This profession, I submit, will attract the best brains in the country. It will include people from many disciplines for the profession of applied entomology of the future will require the broadest kinds of biological, physical, mathematical and chemical expertise. Societies such as the Entomological Society of Ontario have an important role to play in the future of economic entomology. Let us make sure that as the needs for applied entomologists become more apparent, we are in a position to meet the demand.

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OVIPOSITION AND DEVELOPMENT OF *HYLEMYA BRASSICAE* (BOUCHE) (DIPTERA: ANTHOMYIIDAE) ON CRUCIFEROUS WEEDS[1]

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Abstract

It is known that the adult cabbage maggot, *Hylemya brassicae* (Bouché) is stimulated to oviposit by glucosinolates (mustard oil glucosides) present in its host plants. Although all crucifers are believed to contain glucosinolates, in a field and laboratory study of thirteen cruciferous weeds, only some elicited oviposition and supported development of this insect. These were *Hesperis matronalis* L., *Barbarea vulgaris* R. Br., *Sisymbrium loeselii* L., *Lepidium densiflorum* Schrad. and *Sinapis arvensis* L., the last being the least attractive host.

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Introduction

Larvae of the cabbage maggot, *Hylemya brassicae* (Bouché) are believed to feed exclusively on cruciferous plants, usually on the roots. A primary factor determining infestation is the potential of a plant species to elicit oviposition by the adult insect. There is some evidence that oviposition of *H. brassicae* is stimulated by the so-called secondary plant substances, the glucosinolates (Traynier, 1965, 1967). The glucosinolates, also referred to as mustard oil glucosides or thioglucosides, constitute a well-defined and unique class of chemicals, restricted to the Cruciferae and a few other botanical families. Most crucifers contain more than one glucosinolate and they appear to be distributed throughout the entire plant (Kjaer, 1960). The importance of glucosinolates or their aglucones as feeding or oviposition stimulants or attractants of many other crucifer-feeding insects is now well established (see Schoonhoven, 1972).

All cultivated crucifers of the genus *Brassica* are attacked by the cabbage maggot. Some, notably chinese cabbage, rutabaga and turnip, elicit more oviposition than many others tested (Doane and Chapman, 1962; Pond and Moore, 1965; Mukherji, 1969). Radish (*Raphanus sativus* L.) and horse radish (*Armoracia rusticana* Gaertn., Mey. and Scherb.) are also attacked. Among cruciferous weeds, wild mustard (*Sinapis arvensis* L.) [preceding three botanical names ours], hedge mustard (*Sisymbrium officinale*) and yellow rocket (*Barbarea vulgaris*) have been recorded as hosts (Slingerland, 1894; Schoene, 1916; Caesar, 1922). In tests with various plant species belonging to different families, Traynier (1965) found that eggs were laid near each of eight species of Cruciferae other than the common brassica crops tested. These were *Sisymbrium officinale* (L.) Scop., *Sinapis arvensis* L., *Sinapis alba* L., *Rorippa nasturtium-aquaticum* (L.) Hayek, *Lepidium sativum* L., *Cheiranthus cheiri* L., *Cardamine hirsuta* L., and *Armoracia rusticana* Gaertn., Mey. and Scherb. In addition, eggs were laid near *Reseda odorata* L., *R. luteola* L. (Resedaceae), *Tropaeolum majus* L., *T. peregrinum* var. *canariense* (Tropaeolaceae), *Capparis spinosa* L., and *C. inermis* L. (Capparidaceae). These contain glucosinolates. Eggs were not laid near five species of other families lacking glucosinolates. Although reported to contain glucosinolates, *Plantago major* L. (Plantaginaceae) and *Limnanthes douglasii* R.Br. Limnanthaceae) did not elicit oviposition in Traynier's study. At least one crucifer,

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shepherd's-purse (*Capsella bursa-pastoris*), is known to be immune to attack (Slingerland, 1894; Schoene, 1916). Although beans and beet are hosts recorded in the literature (Gibson and Treherne, 1916) no eggs were laid near these in Traynier's (1965) tests.

We studied the oviposition and development of *H. brassicae* on cruciferous weeds, under both field and laboratory conditions, as a preliminary step for a detailed analysis of the relationship between glucosinolates and host selection behaviour.

Methods

Field Studies

Ten species of cultivated weeds (Table I) were studied in 1971. They were grown in the greenhouse from seeds and transplanted to the field when about 1-month old. Five plants of each species were planted at random, on May 18, near an experimental plot of rutabaga at Preston, Ontario. On each of three occasions, (May 25, May 28, June 14), the soil around two plants of each species was collected and examined for eggs of *H. brassicae*. All five plants of each species were later examined for larvae and puparia, two of each on June 17, three on October 25.

In the same year, some wild cruciferous weeds found adjacent to the experimental plot were also examined. This was done in the second week of July when the second generation maggots were established in rutabaga. For each species examined, 20 soil cores each containing one plant root was brought to the laboratory and checked for larvae and puparia. Where no maggot infestation was found in this sampling, additional large numbers of plants were pulled and examined for larvae.

Two species (Table I) were added to the study in 1972. Five plants of each species, about 1-month old, were transplanted to the field on June 14 and examined for larvae and puparia in early October.

Greenhouse and Laboratory Studies

Eleven species of weeds (Table II) were tested for oviposition, in the presence of radish, under greenhouse conditions. Fifty gravid females and 50 males were confined in a screened cage, 6 x 12 x 6 ft (1.8 x 3.6 x 1.8 m). The flies were given water, honey, and a mixture of dry brewer's yeast and yeast hydrolysate. At intervals of three days, three species of plants, one of them being radish, were placed inside the cage. The radishes were about 1-month old; the weeds, about 2-3 months old. Three potted plants of each species were arranged in a randomized block. The number of eggs laid around each plant during the 3-day period was determined. Another test with radish and two other weed species followed immediately. At the start of each test, 10 pairs of flies, not older than three days, were added to the cage to compensate for deaths. Since no interval was given between the tests, the flies were not under stress. The use of radish as standard also ensured that at least one host species was present at all times. The significance of the difference in the mean number of eggs between species was tested by the *t*-test after logarithmic transformation of the data.

To study the development of larvae on weeds, either eggs or newly hatched larvae were placed in the soil close to the roots of plants grown in pots. The plants, 1-2 months old, were kept in a growth chamber at 20°C and 16-hr photoperiod. The soil was examined for puparia at 24-27 days from the start of the experiment. For most species, several replicated tests were made.

Results and Discussion

Of the thirteen weed species studied under field conditions (Table I), only Dame's-rocket, yellow rocket, tall hedge mustard, wild mustard, and common peppergrass were infested by *H. brassicae*. The immature stages of *H. brassicae* follow a negative binomial distribution in cabbage, under field conditions (Mukherji and Harcourt, 1970). Therefore, in the present tests with five plants of each species, absence of infestation cannot be taken as conclusive. In the case of wormseed mustard, shepherd's-purse and marsh yellow cress, however, a large number of wild plants were also examined but no infestation was found.

As expected, in laboratory tests, all the five host species mentioned above supported the development of *H. brassicae* when eggs or newly hatched larvae were placed around potted plants (Table I). In addition, marsh yellow cress yielded some puparia. Larval feeding was noticed in flixweed but no puparia resulted, possibly because the experimental plants were small and most succumbed to the injury. In conformity with the field observations, none of the other weed species supported development of the insect.

In preference tests with potted plants (Table II), no eggs were laid near any of the eight weed species that were not infested under field conditions. These included marsh yellow cress and flixweed which supported larval growth when artificially infested. It must be noted that all these species were tested in the presence of other host plants. However, since some host plants will be present in most natural situations, it may be concluded that the eight weed species which did not elicit oviposition in the present tests will not support *H. brassicae* populations under natural conditions. Of the five weed species that were infested under field conditions, only Dame's-rocket, common peppergrass and wild mustard were available for oviposition preference tests. Among radish, rutabaga and the above three, wild mustard was the least attractive (Table II). Radish elicited more oviposition than rutabaga ($P < 0.05$). There was no significant difference in the mean number of eggs laid between radish and either Dame's-rocket or common peppergrass. It follows then that both Dame's-rocket and common peppergrass are more attractive than rutabaga. Based on the numbers of puparia recovered under field conditions (Table I), yellow rocket also appears to be more attractive than rutabaga. However, large scale experiments are necessary to establish the relative attractiveness of the various species, especially since size differences among the species, due to different growth rates, may have contributed to differences in attractiveness. It is also known that radish may be more attractive at some stages of growth than at other times (Doane and Chapman, 1962). In the present study, field and laboratory data show that wild mustard is the least attractive of all the host species studied.

Dame's-rocket, tall hedge mustard and common peppergrass are new host records for *H. brassicae*.

It is clear that only some crucifers elicit oviposition by *H. brassicae,* although all crucifers are believed to contain glucosinolates. Further studies are in progress to elucidate the relationship between glucosinolates and the oviposition behaviour of this insect. There is little doubt that glucosinolates stimulate oviposition by *H. brassicae*. Perhaps, the non-host crucifers contain inhibitory chemicals that override the stimulatory effect of glucosinolates.

TABLE I. Oviposition and development of *Hylemya brassicae* on cruciferous weeds.

Plant Species	FIELD OBSERVATIONS (1971)			LABORATORY OBSERVATIONS		
	No. of eggs per plant, total of 3 samplings	No. of larvae and puparia per plant		No. of puparia resulting from eggs or newly hatched larvae		
		June 17	Oct. 25	Expt. 1[c]	Expt. 2[c]	Expt. 3[c]
Rutabaga (*Brassica napobrassica* Mill.)	> 11	—	4	8	12	7
Dame's-rocket (*Hesperis matronalis* L.)	134	5	44	36	15	—
Yellow rocket (*Barbarea vulgaris* R. Br.)	22	11	71	12	9	—
Wild mustard (*Sinapis arvensis* L.)	2	0	1 (2)[a]	3	1	6
Common peppergrass (*Lepidium densiflorum* Schrad.)	3	0	6	4	2	10
Tall hedge mustard (*Sisymbrium loeselii* L.)	—	—	— (10)[b]	—	3	—
Field peppergrass (*Lepidium campestre* R. Br.)	0	0	0	0	0	0
Wormseed mustard (*Erysimum cheiranthoides* L.)	0	0	0 (0)[a]	0	0	0
Tall wormseed mustard (*Erysimum hieracifolium* L.)	—	0	0 (0)[b]	—	—	0
Hoary alyssum (*Berteroa incana* L.)	0	0	0	0	0	0
Flixweed (*Descurania sophia* L.)	0	0	0	—	—	+[d]
Ball mustard (*Neslia paniculata* (L.) Desv.)	0	0	0	—	—	—
Shepherd's-purse (*Capsella bursa-pastoris* (L.) Medic.)	0	0	0 (0)[a]	0	0	0
Marsh yellow cress (*Rorippa islandica* (Oeder) Borbas)	—	—	— (0)[a]	0	2	3

[a]Based on examination of wild plants. [b]Based on examination of cultivated plants in 1972. [c]Expt. 1, 50 eggs/pot with variable no. of plants; Expt. 2, 10 larvae each in 2 pots containing one plant each; Expt. 3, 10 larvae each in 2 pots containing variable no. of plants. [d]Host plants dead due to larval feeding.

Table II. Percentage distribution of eggs around each of three species of plants in oviposition preference tests.

Expt. no.	Plant species	Percentage distribution of eggs	Total eggs deposited
1.	Radish	76	458
	Rutabaga	24	
	Hoary alyssum	0	
2.	Radish	37[a]	509
	Dame's-rocket	63[a]	
	Shepherd's purse	0	
3.	Radish	62[b]	518
	Common peppergrass	48[b]	
	Wormseed mustard	0	
4.	Radish	95	169
	Wild mustard	5	
	Marsh yellow cress	0	
5.	Radish	100	256
	Field peppergrass	0	
	Tall wormseed mustard	0	
6.	Radish	100	285
	Flixweed	0	
	Ball mustard	0	

In each experiment, 3 potted plants of each species were exposed to about 50 male and 50 female flies for 3 days.
The difference between means followed by the same letter were not statistically significant at the 5 per cent level. Test applied to log actual counts.

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OBSERVATIONS ON COCCINELLIDAE IN CORN FIELDS IN ESSEX COUNTY, ONTARIO

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Abstract

Three species of coccinellid adults predominated in corn fields, namely, *Hippodamia convergens* Guérin-Méneville, *H. tredecimpunctata tibialis* (Say), and *Coleomegilla maculata lengi* Timberlake. Species which occurred in low numbers each year or only in occasional years included: *Adalia bipunctata* (L.), *Cycloneda sanguinea* L., *H. parenthesis* (Say), and *Coccinella transversoguttata* Faldermann. Coccinellids were unable to prevent damage by the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), because large numbers were not present until after aphid infestations had peaked and caused most of the injury which was likely to occur.

* * * * * *

Introduction

It was noted during a study of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), that coccinellids comprised the largest group of predators of aphids. In this paper the species, their relative abundance, and importance as predators of aphids in field corn in Essex County, Ontario are discussed.

Methods

Data on species of coccinellids and their relative abundance were obtained by having two investigators record every adult observed on plants in plots of field corn. Observations were usually made weekly and were always for a specified length of time. In addition to noting the species, a record was made of the area on the plant where each beetle was found, to ascertain if there were any differences in vertical distribution between species. After the ears had developed, husks were turned back on every third or fourth plant examined to detect beetles which were hidden from view. The search was always conducted during the middle part of the day and never in inclement weather when the beetles might have sought shelter. Beetles on the ground or in flight were ignored.

In 1967 and 1968 each of two corn fields located in different areas on the research station were examined for 30 minutes. One of these fields was planted to a single hybrid where plant development and susceptibility to aphid infestations were relatively uniform. The other field had several hybrids and thus provided a variation in plant development and susceptibility to aphids. In 1969 and 1970 only a single-hybrid field was examined but the observation period was extended to 40 minutes.

Observations of immature stages of the coccinellids were also made. Actual counts of larvae and pupae were never taken, but populations were estimated weekly as being high, moderate or low. When combined with data on the adults this provided information on how closely the peak populations of aphids and coccinellids coincided. A minimum of 15 plants were examined each week to observe the numbers of coccinellid eggs deposited, their location on the plants, and the level of aphid infestation which existed.

Results and Discussion

It was found that three species of coccinellid adults predominated throughout the four years of the study, namely, *Hippodamia convergens* Guérin-Méneville, *H. tredecimpunctata tibialis* (Say), and *Coleomegilla maculata lengi* Timberlake (Tables I to IV). Only small numbers of the following were observed: *Adalia bipunctata* (L.), *Cycloneda sanguinea* L., and *H. parenthesis* (Say). A plausible explanation for the difference in abundance for several of these species was provided by Putman (1964). He found that *A. bipunctata* was the predominant species on peach trees and that *C. m. lengi* and the *Hippodamia* spp. only occurred in low numbers. Putman concluded that *A. bipunctata* was arboreal in habit whereas the latter species were more adapted to low-growing plants. Of special interest in the present investigation was the yearly difference in species domination, particularly in the case of *H. convergens*. In 1967 it comprised 88.8% of all coccinellid adults observed (Table I), but only 6.8% in 1968 (Table II). The only other known study of this nature in Ontario was conducted by Smith (1971) in the Belleville area. In his one-year census of species, *H. convergens, A. bipunctata* and *C. sanguinea* were never recorded in corn fields. However, he found *Coccinella novemnotata* Hbst. and *C. trifasciata perplexa* Muls., species which were not observed in this study.

TABLE I. Numbers of coccinellid adults observed during a weekly 30-minute search in two corn fields, 1967.

Date	Numbers observed				
	Hippodamia convergens	*Hippodamia tredecim-punctata tibialis*	*Coleomegilla maculata lengi*	Other species[3]	Total no. observed
Field I, comprised of 8 hybrids					
July 6	1	1	1	0	3
" 14	6	1	1	0	8
" 21[1]	20	1	1	0	22
" 28	14	0	0	0	14
Aug. 3[2]	1	1	0	0	2
" 11[2]	126	0	0	0	126
" 17	222	1	1	0	224
" 24	680	1	0	0	681
" 31	220	0	1	0	221
Sept. 7	119	9	3	1	132
" 14	136	7	14	1	158
" 25	68	4	3	3	78
Totals:	1613	26	25	5	1669
Field II, comprised of 1 hybrid					
July 6	3	4	2	0	9
" 14	7	2	4	1	14
" 21[1]	16	0	3	0	19
" 28	6	4	8	0	18
Aug. 3[2]	6	1	2	1	10
" 11	79	15	1	1	96
" 17	181	26	22	2	231
" 24	129	20	39	3	191
" 31	97	6	12	3	118
Sept. 7	49	8	17	0	74
" 14	46	4	7	2	59
" 25	73	8	4	3	88
Totals:	692	98	121	16	927

[1]Start of pollination.
[2]Large numbers of larvae and pupae observed.
[3]Species observed were: *Adalia bipunctata, Cycloneda sanguinea, Hippodamia parenthesis.*

TABLE II. Numbers of coccinellid adults observed during a weekly 30-minute search in two corn fields, 1968.

Date	Numbers observed				
	Hippodamia convergens	*Hippodamia tredecim-punctata tibialis*	*Coleomegilla maculata lengi*	Other species[1]	Total no. observed
Field I, comprised of 3 hybrids					
July 4	0	0	3	0	3
" 11	0	3	2	0	5
" 18	0	5	4	0	9
" 26[2]	0	1	2	0	3
Aug. 6[3]	0	8	4	0	12
" 15	0	27	28	0	55
" 22	4	51	19	2	76
Sept. 6	0	15	8	0	23
" 16	1	8	12	0	21
Totals:	5	118	82	2	207
Field II, comprised of 1 hybrid					
July 4	0	0	10	0	10
" 11	0	2	6	1	9
" 18	1	6	11	0	18
" 26[2]	9	9	16	1	35
Aug. 6[3]	0	2	1	0	3
" 15	14	105	5	0	124
" 22	1	20[4]	67	0	88
Sept. 6	5	25	12	0	42
" 16	3	10	9	1	23
Totals:	33	179	137	3	352

[1]Species observed in Field I: *Adalia bipunctata, Cycloneda sanguinea;* Field II: *C. sanguinea, Hippodamia parenthesis.*
[2]Start of pollination.
[3]Moderate numbers of larvae and pupae observed.
[4]The majority of this species was hidden under ear husks. Despite the low numbers recorded, it was the predominant species.

TABLE III. Numbers of coccinellid adults observed during a weekly 40-minute search of a corn field[1], 1969.

Date	Numbers observed				
	Hippodamia convergens	*Hippodamia tredecim-punctata tibialis*	*Coleomegilla maculata lengi*	Other species[2]	Total no. observed
July 18	0	2	1	0	3
" 22	0	2	19	1	22
" 31[3]	12	17	40	0	69
Aug. 5	4	8	7	1	20
" 13	4	2	14	4	24
" 19[4]	1	38	14	0	53
" 28	39	75	67	6	187
Sept. 5	3	29	102	0	134
" 11	9	22	119	2	152
" 19	5	6	36	1	48
" 26	0	17	29	0	46
Totals:	77	218	448	15	758

[1]Field was comprised of one hybrid.
[2]Species observed were: *Adalia bipunctata, Cycloneda sanguinea.*
[3]Start of pollination.
[4]Moderate numbers of larvae and pupae observed.

TABLE IV. Numbers of coccinellid adults observed during a weekly 40-minute search of a corn field[1], 1970.

Date	Numbers observed				
	Hippodamia convergens	*Hippodamia tredecim-punctata tibialis*	*Coleomegilla maculata lengi*	Other species[2]	Total no. observed
July 6	0	0	1	1	2
" 13	0	1	1	0	2
" 23	0	0	5	1	6
" 29[3]	1	3	2	2	8
Aug. 6	0	0	6	0	6
" 11	6	16	1	0	23
" 17	3	16	3	3	25
" 24	12	25	0	0	37
" 31	8	6	2	5	21
Totals:	30	67	21	12	130

[1]Field was comprised of one hybrid.
[2]Species observed were: *Adalia bipunctata, Cycloneda sanguinea.*
[3]Peak of pollination was on July 27 to 29.

A *Stethorus* sp., thought to be *S. punctillum,* was observed on corn plants in some years, but it could not be confirmed that it was feeding on *R. maidis.* Putman (1955, 1964) and Wheeler *et al.* (1973) consider this species to be a highly specialized predator of tetranychid mites. *Coccinella transversoguttata* Faldermann was never found between 1967 and 1970 when records were made, but large numbers were observed in a corn field shortly after the termination of pollination in 1972.

The highest populations of coccinellids occurred in 1967, which was also the year when *R. maidis* populations were the highest. However, there was no apparent relation between aphid and coccinellid numbers during the years 1968 to 1970. The period of maximum adult activity was usually preceded by very low numbers of adults but moderate to large numbers of larvae and pupae. This suggested that the large numbers of adults which sometimes occurred after the plants had pollinated, resulted mainly from reproduction within the field rather than movement to the field. Although *C. m. lengi* adults are known to feed on pollen as well as aphids (Smith, 1965), there was no evidence that this species was attracted to corn fields at pollination. No major differences in species composition occurred between a field planted to several hybrids and one planted to a single hybrid (Tables I and II).

It was found that the *Hippodamia* spp. were more common than *C. m. lengi* on the upper portions of plants, particularly in July when aphid infestations were almost confined to the tassel and whorl leaves (Table V). *C. m. lengi* was rarely observed on the tassel. When aphids moved down the plants, which commonly occurs during the pollination period, there was a corresponding downward movement of the *Hippodamia* spp. Thus a large percentage of all three major species were present in the central area of the plants. *C. m. lengi* was always the dominant species on the lower parts of the plants. Similar differences in distribution for these species were observed by Ewert and Chiang (1966) on corn in Minnesota. They deduced from their experiments that *H. convergens* feeds mostly on aphids and is very resistant to desiccation. It can therefore successfully occupy the upper regions of vegetation. *C. m. lengi* consumes both aphids and pollen, but is susceptible to desiccation, thus it occupies lower regions on the plants where there is more pollen and a higher humidity. *H. t. tibialis* was not so well adapted. Although it feeds mainly on aphids, it is susceptible to desiccation. Further evidence that *H. convergens* adults are very adaptable in regard to the height at which they will

TABLE V. Distribution of adults of three species of Coccinellidae on different parts of corn plants, 1967-1969.

Month plants examined[1]	Species	Percentage of each species which occurred at five different locations[2]				
		Tassel	Upper leaves and stalk	Middle leaves and stalk	Ear	Lower leaves and stalk
July	*Hippodamia convergens*	40.2	22.8	26.1	3.3	7.6
	H. tredecimpunctata tibialis	26.8	37.5	33.9	0.0	1.8
	Coleomegilla maculata lengi	3.8	30.3	46.2	3.8	15.9
August	*H. convergens*	2.9	14.3	55.7	17.3	9.8
	H. t. tibialis	1.0	21.6	53.6	12.8	11.0
	C. m. lengi	0.7	6.9	55.6	17.1	19.7
September	*H. convergens*	0.3	11.1	65.3	17.6	5.7
	H. t. tibialis	0.5	13.7	44.0	38.5	3.3
	C. m. lengi	0.0	7.3	48.7	32.8	11.2

[1]Counts were made weekly and averaged.
[2]Data for three years were averaged.

feed was obtained in 1967 when several dozen were observed on the ground feeding on *Rhopalosiphum padi* (L.) which had vacated severely-infested plants in one area of a field.

Numbers of eggs deposited per plant often bore little relationship to size of aphid infestations. Lightly-infested plants often had more coccinellid eggs than nearby moderately- to severely-infested plants, and neighboring plants with similar aphid infestations had large variations in egg numbers. It was also difficult to relate the numbers of eggs counted on one date to the numbers of larvae observed in a subsequent examination. This indicates that many larvae die, fall prey to predators, or leave the plants. The percentage of eggs deposited on the upper leaves was twice as high in the prepollination period as in the postpollination period (Table VI). However, the middle leaves were the favored sites for oviposition regardless of the stage of plant development or aphid distribution. No eggs were found on tassels or the upper surfaces of leaves when these data were collected and very few were placed on stalks.

Table VI. Location of coccinellid eggs on field corn plants during three stages of plant development.

Stage of plant development	Percentage of eggs at each location					
	Upper leaves	Middle leaves	Lower leaves	Stalk		
				Upper	Middle	Lower
Prepollination	32.9	43.8	23.3	0.0	0.0	0.0
Pollination	27.5	48.9	23.6	0.0	0.0	0.0
Postpollination	16.3	49.0	31.0	0.0	0.0	3.7

Articles on corn insects sometimes advise that it is uneconomical to treat fields for *R. maidis* since insect predators usually keep it in check. Although it is true that applications of insecticides would often be uneconomical, there is no evidence from work conducted at Harrow that coccinellids, the most prevalent group of predators, provide any meaningful control. A previous investigation showed that most of the aphid buildup and feeding injury occurs before and during pollination (Foott and Timmins, 1973), while the present investigation revealed that moderate to large numbers of coccinellid larvae and adults are not present until after pollination.

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LABORATORY COMPARISON OF THE STOMACH, CONTACT AND FUMIGANT ACTION OF CHLORPYRIFOS AGAINST THE DARK-SIDED CUTWORM (LEPIDOPTERA: NOCTUIDAE)

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Abstract

Laboratory tests were conducted to determine the toxic action of chlorpyrifos on fourth- to sixth-instar larvae of the dark-sided cutworm, *Euxoa messoria* (Harris). The stomach, contact and fumigant action of the insecticide was determined, using a chromatography sprayer. The results showed that the stomach action of chlorpyrifos was much quicker and significantly better the first day after treatment, than the contact or fumigant action and was the only treatment causing 100% mortality of the larvae during the period of this study. There was no significant difference between contact and fumigant effects.

* * * * * *

Introduction

The dark-sided cutworm, *Euxoa messoria* (Harris), is one of the most important pests of flue-cured tobacco in Ontario (Cheng, 1971a). Flue-cured tobacco is grown in rotation with rye. The rye crop is seeded in the fall and ploughed under the following spring. Adults of the dark-sided cutworm lay their eggs in the soil from August to October, and the eggs enter diapause (Cheng, 1973a). They hatch from late March to early April, depending upon the weather, and the early larval instars feed on the rye crop. When the rye is ploughed under and the tobacco seedlings planted, the larvae then attack the tender transplants.

During recent years, increased attention has been given to insecticide residues in tobacco. Laboratory and greenhouse studies have indicated that DDT translocates from treated nutrient solution, quartz sand and field soil (Fox loamy sand) into the aerial portions of tobacco plants (Rosa and Cheng, 1973, 1974). In Ontario, DDT applied to either the rye cover crop or the soil surface provided effective control of this species (Cheng, 1971b, Harris and Svec, 1970). The use of DDT was restricted in 1970 and banned in 1972 (Ont. Dept. Agric. Food, 1972), and new, more toxic but less persistent, compounds are being rapidly substituted.

Cheng (1971b, 1973b) and Harris *et al.* (1971, 1973) found that chlorpyrifor (Dursban®) provided effective control with either rye cover crop or soil treatments and at lower rates of application and is an acceptable substitute for DDT in controlling this species in the field. Chlorpyrifos has been registered and recommended since 1970, but because of its short residual action, timing of application is critical. Detailed studies on the stomach, contact and fumigant action of chlorpyrifos against the dark-sided cutworm were required in order to make more efficient use of the compound. This report summarizes laboratory tests conducted to assess the efficacy of the different toxic actions of chlorpyrifos.

Materials and Methods

Diapausing eggs of the dark-sided cutworm were stored at 32 ± 2°F and later hatched in moist sand in a 128 oz jar at 72 ± 2°F and 12 hr photoperiod.

Contribution No. 92

First-, second-, and third-instar larvae were fed fresh rye shoots and later instars, tobacco leaves. All test larvae were fourth- and fifth-instar larvae.

Chlorpyrifos (Dursban® 4 EC), as a stomach, contact and fumigant poison, was applied at the rate of 0.5 lb actual per acre in an amount of water equivalent to 20 gal per acre, using a 4.2 oz (125 ml) chromatography sprayer. There were four treatments, as described below, and an untreated check. Two replicates, each containing 10 larvae, were used for each treatment and the whole experiment was repeated four times. Following treatments, larvae were placed individually in 7-oz waxed paper cups and reared in an environmental chamber maintained at 72 ± 2°F, 65 ± 5% R.H. with a 12-hr photoperiod.

(a) Stomach action: Fresh tobacco leaves were placed on a 12 square inch area and sprayed with chlorpyrifos. The treated leaves were air-dried and placed in the waxed paper cups, as food supply for the larvae for two days and then were replaced by fresh, untreated leaves. The cups were covered individually with a single layer of tissue paper to prevent the larvae climbing out.

(b) Fumigant action — cup sealed: Filter paper disks 2⅛ inches (5.5 cm) in diameter were placed on a 12 square inch area and sprayed with chlorpyrifos. The treated filter papers were placed individually in the bottom of each cup. A circular aluminum screen disk 2¼ inches in diameter was put in each cup about 1.5 inches above the treated filter paper, and then a larvae was placed on the screen in each cup containing untreated fresh tobacco leaves. The food was replaced every second day. The cups were sealed with a flat glass plate to prevent leakage of the chlorpyrifos vapour (Fig. 1).

(c) Fumigant action — cup not sealed: The procedure for this test was the same as (b) except that the cups were not sealed.

(d) Contact action — soil treatment: To simulate field conditions, half an inch of air-dried and insecticide-free sandy soil was placed in a flat (12 x 12 x 2 inches). Chlorpyrifos was then applied to the soil surface. Following treatment, ten larvae were placed on the soil surface for one hour to ensure good contact with the insecticide and then the larvae were placed individually in waxed paper cups with untreated tobacco leaves. Every 24 hours, the survivors were placed on the same soil surface for one hour and then returned to their individual cups. This procedure was repeated for three days.

In all tests, mortality counts of the larvae were made daily for four days. The percent mortalities were transformed into angular units (Steel and Torrie, 1960) and significance of the treatments was determined by the analysis of variance and Duncan's multiple range test (Duncan, 1955).

Results and Discussion

Mortality of the larvae within each treatment of two replicates, in the series of four experiments, was consistent with the exception of the contact action which resulted in a variable mortality from 50% to 100%. This variability may be attributed to differences in soil moisture (Harris and Svec, 1970). Since there were no significant differences in this series of four experiments, the results were averaged, analysed, and are presented in Table I.

The mortality in all treatments was significantly higher than that of the untreated check (Table I). Although mortalities from the four different treatments of chlorpyrifos, four days after treatment, were not significantly different, mortalities from the stomach action of chlorpyrifos were significantly higher than mortalities from the fumigant or contact action the first day after treatment. Previous studies (Harris and Svec, 1968, Harris *et al.* 1969) showed that chlorpyrifos

Table I. The stomach, fumigant and contact action of chlorpyrifos (Dursban® 4 EC) on fourth- to sixth-instar larvae of the dark-sided cutworm.

Treatment		Mean % mortality*			
Method	Rate (lb AI/acre)	Days after treatment			
		1	2	3	4
Stomach	0.5	90a	100a		
Fumigant (sealed)	0.5	58b	78ab	93a	95a
Fumigant (not sealed)	0.5	25b	50b	63a	75a
Contact	0.5	20b	53b	73a	73a
Untreated check	—	0c	0c	0b	0b

*Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

was more effective when applied to rye as a stomach poison than when applied for its contact effects to soil. The fumigant action of chlorpyrifos resulted in a higher mean percent mortality than the contact action but differences were not significant. The contact action of chlorpyrifos caused the least mean percent mortality and this is one of the reasons why soil treatments require higher rates than rye treatments in order to provide the same degree of control under field conditions (Cheng 1971b, 1973b, Harris *et al.* 1971).

Because of the volatilization of chlorpyrifos (Smith, 1966), there has been a controversy about the proper time to plough following rye treatment. Data from the two different fumigant treatments of this compound would indicate that the effectiveness of chlorpyrifos was not influenced by the time interval between treatment and ploughing. For the maximum utilization of all toxic actions of chlorpyrifos, the rye cover crop should be ploughed two to three days after treatment to reduce the volatilization of chlorpyrifos, and still give the dark-sided cutworm larvae time to feed on the treated rye.

This experiment emphasizes the value of spraying rye or tobacco plants to obtain stomach action rather than relying on the contact action of soil treatments. The stomach action is the major cause of early cutworm mortality (100% in two days), while the contact and fumigant actions are less rapid. The faster mortalities obtained by the stomach action suggest that, in future studies on dark-sided cutworm control, less emphasis should be placed on soil treatment and more emphasis on rye or tobacco plant treatment. The latter treatment has the multiple merits of using less insecticide, avoiding the critical factor of soil moisture, reducing insecticide pollution in our environment, and at the same time, providing better control of the target insects.

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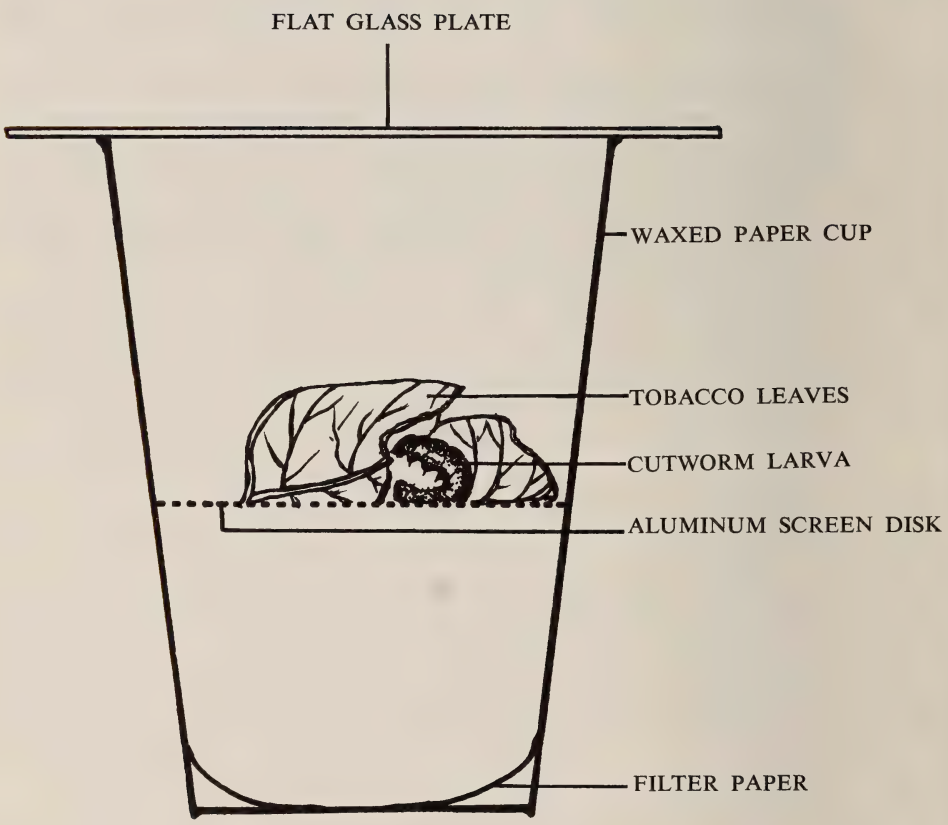

FIGURE 1. The device used for the chlorpyrifos fumigant action tests.

A REVIEW OF INSECTS, SPIDERS AND MITES PREDACEOUS ON BUMBLE BEES (BOMBINAE) IN NORTH AMERICA

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Abstract

Ants, other insects, and mites affect bumble bee nests. In the field 22 species of asilids, phymatids, a sphecid and six species of spiders are known to prey on Bombinae.

* * * * * *

Bumble bees are the chief pollinators of red clover, and provide supplementary pollination to apples, cranberries, blueberries, alfalfa, clovers, peanuts, currants, sunflowers, cotton and 25 other fruits, vegetables, agricultural crops, and flowers worth over $790 million per year in North America. However, low and fluctuating populations of bumble bees limit their commercial importance.

All the known predators of bumble bees are facultative. Their effect on bumble bees depends on (1) the extent to which predator and bumble bee populations are present together in time and space and (2) the degree to which the predator utilizes bumble bees in its diet. Predators attack either the nest of bumble bees, or bees outside the nest in the field, and each predator seldom if ever attacks at both sites. The natural enemies of N. American *Bombus* were reviewed previously by Frison (1926) and Plath (1934).

i) Predators of adults in the field

a) Insects as predators

Bromley (1914, 1930, 1934, 1936, 1949), Rau (1922), Brown (1929), Plath (1934), Fattig (1933, 1945), Lavigne and Holland (1969), and Rogers and Lavigne (1972) have recorded the following asilids attacking bumble bees (Table I).

Many of these 22 species of predators are most active after most bumble bee queens have established their nests, and so the few asilids present in the spring have little effect on foundress queens. Most of the prey records do not state the caste attacked, but it seems their main effect as predators is on males and workers. Bumble bees are apparently an important part of the diet of *Mallophora orcina* (Weid.) only (Fattig, 1933; Bromley, 1936).

The main prey recorded for the ambush bug *Phymata pennsylvanicus americanus* Melin were tachinid, callophorid, conopid and syrphid flies, halictid bees as well as *B. impatiens, Psithyrus variabilis* and many other insect families (Baldulf 1939, 1940, 1943). Baldulf noted that the larger females require more prey. Eight of over 4,300 male and worker bumble bees observed on flowers during two years of field studies at Guelph, Ontario were killed by *P. pennsylvanicus*: viz. *B. perplexus* 1 ♀, *B. fervidus* 2 ♀, *B. impatiens* 1 ♀, *B. rufocinctus* 1 ♀, *B. affinis* 3 ♂. Captured prey were observed from 18th July to 31st October, with 37 of the 49 prey records being in August and September. On August 22 a medium sized *B. impatiens* worker escaped from a female *P. pennsylvanicus,* which had

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Table I. The activity periods and Bombinae prey of North American Asilidae adults.

Predator	Hosts	Period of adult activity	Reference Numbers
**Proctacanthus rufus* Will.	*Bombus* sp.	May-September	8, 10, 11, 15, 22
**P. philadelphus* Mq.	*B. affinis* Cress., *B. bimaculatus* Cress., *B. perplexus* Cress., *B. impatiens* Cress., *B. vagans* Sm.	June-October	7, 8, 11, 22, 24
P. milbertii Mq.	*B. fervidus* (F.), *B. pennsylvanicus* (DeG.), *B. impatiens, B. nevadensis auricomus* Robt.	August-November	10, 12, 33
P. hinei Bromley	*Psithyrus* sp. female	June 22-Aug. 20	10
P. micans Schiner	*B. huntii* Greene	July 18-Aug. 22	34
Mallophora orcina (Weid.)	*B. impatiens, B. griseocollis* (DeG.) *B. affinis, B. pennsylvanicus P. variabilis* (Cress.), *Psithyrus* sp.	June 24-Sept. 28	10, 14, 17 24
M. bomboides (Weid.)	*B. fraternus* Sm.	Aug.-Oct.	15
Promachus barstardii Mq.	*B. fervidus*	May-August	7, 10, 15, 22, 24
P. dimidiatus Curran	*Bombus* sp.	June 23-July 22	21
**P. fitchii* Osten Sacken	*B. vagans*	June-August	7, 11, 22
Efferia femorata (Mq.)	*B. bimaculatus*	July-August	15
E. interrupta (Mq.)	*B. fraternus*	May 1-Oct. 19	10, 15
E. pogonia (Weid.)	*B. pennsylvanicus*	May 28-Oct. 30	10, 15, 22 28
Asilus erythocnemius Hine	*B. perplexus*	June 16-Sept. 26	7, 15, 22, 28
**Diogmites basalis* (Walk.)	*B. impatiens, B. vagans, B. fervidus*	June-September	2, 7, 11, 22, 24
D. esuriens Bromley	*B. pennsylvanicus*	June-August	2, 13
D. symmachus Loew	*B. pennsylvanicus*	June 4-Oct. 14	2, 10
**Laphria grossa* (F.)	*B. fervidus, B. affinis, B. perplexus*	May 29-Aug. 22	11, 15, 22, 24, 28, 30
L. saffrana F.	*B. impatiens*	May 23-June 23	15, 24
L. sericea Say	*B. perplexus*	May 23-August	15, 28
L. fernaldi (Back)	*Bombus* sp.		13
L. thoracica F.	? *Bombus* sp.	May-August	7, 11, 22, 24, 28, 30

**B. terricola* Kirby prey of one or more of these species ref. 11

been holding the bee by the corbicula, after a struggle of at least twelve minutes. It seems improbable that *Phymata* has the ability to catch the few *Bombus* queens foraging in the autumn.

The sphecid wasp *Philanthus bicinctus* (Mickel) unlike the previous predators, provisions its nest mainly with *Bombus*, eight species being known as hosts (Armitage, 1965). He reported it was active from July 16 to August 23, and preferred young bees.

Some of the bumble bee queens, workers, and males that visit honey bee hives may escape, but more frequently they are killed (Plath, 1927; Morse and Gray, 1961). Workers and queens which survive, could pick up *Nosema apis* Fantham and Porter (Showers, Jones and Moeller 1967). Honey bees will attack domiciles with bumble bee nests if placed near hives. However, most natural colonies are probably attacked infrequently by honey bees or wasps.

b) Spiders as predators

Bumble bees are caught by web spinning spiders (Epeiridae) and by crab spiders (Thomisidae). Bumble bee queens can fly through or if entangled can escape webs. Turnbull (1960) noted the ability of bumble bees (castes not stated) to thrash out of spider webs. Bumble bees have been recorded from webs of the following spiders (Bilsing, 1920; Plath, 1934):

1. *Epeira gigas* Leach, *B. pennsylvanicus, B. fervidus* 20% of prey,
2. *E. trifolium* Hentz., *B. pennsylvanicus, B. griseocollis* 2% of prey,
3. *E. domiciliorum* Hentz., *B. vagans,*
4. *Argiope aurantia* Lucas, *B. impatiens, B. pennsylvanicus, B. griseocollis,*
5. *A. trifasciata* Forskal, *B. fervidus, B. pennsylvanicus, B. griseocollis.*

The common flower spider, *Misumena vita* (Clark), seizes bumble bee workers on flowers (Lovell, 1915; Plath, 1934). It preys mainly on other insects (Bilsing, 1920; Whitcombe, Exline, and Hunter 1963; Judd 1964).

ii) Predators of bumble bee nests

Most of the insects, which affect nests adversely are parasites. The most important arthropod predators are possibly ants. *Lasius alienus* (Foerster) and *Myrmica lobicornis fracticornis* Emery in particular often disrupt growth of smaller colonies by their attacks (Plath, 1934; Hobbs, Nummi, and Virostek, 1962; Medler, 1962), but other species e.g. *Formica fusca* L. and *Solenopsis molesta* Say cause little disruption. The European earwig, *Forficula auricularia* L. will at times cause queens to desert their nests (Holm 1960). The author has observed it in several nests and seen no evidence of it harming the colony. Pouvreau (1966, 1973) claimed that this earwig attacked eggs and larvae and caused queens to desert their nests. Medler (1959) has suggested that mites attack bumble bee eggs as he found shrivelled eggs and mites together in a mature colony of *B. huntii.*

iii) Conclusions

Frison (1926) and Plath (1934) recorded a spider, a phymatid, ants and at least three asilids as predators of bumble bees. At present at least 30 species of arthropods are known to kill *Bombus* adults, but few, if any, of them are important in the mortality of *Bombus* populations. It is difficult to measure their cumulative effect on worker and male populations, and even harder to assess how much this affects colony strength. Queens in southern Ontario are seldom seen in the field in the autumn, and so have little chance of being preyed on. In the spring, by contrast, queens are most active, but are unlikely to be utilized as prey, because predator populations are low. The available evidence suggests arthropod predators are more important as enemies of bumble bee adults in the field than of the colony.

Acknowledgements

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DASINEURA ACERIS (SHIMER), MIDGE ON SILVER MAPLE (DIPTERA: CECIDOMYIDAE)

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Abstract

Dasineura aceris (Shimer), a pest of silver maple, is reported here from Ontario for the first time. Brief notes are given about the insect and its relation to its host.

* * * * * *

Almost a dozen species of Cecidomyid midges have been recorded from various species of maple in Europe and North America (Barnes, 1951). A few, such as *Cecidomyia ocellaris* (O.S.), the bull's eye midge and *Contarinia negundifolia* Felt, the box elder midge, are recognizable by the galls they form. The majority of species however, appear to be leaf crumplers or folders, not forming discrete galls. On casual observation these deformations may be difficult to distinguish from other types of leaf damage.

The box elder midge has been recorded to be of some economic importance (Peterson, 1951) but Wilson (1966) suggests that there "appears to be little danger of host mortality . . . " Damage by these and other maple midges seems to be more esthetic than lethal.

The species *Dasineura aceris* (Shimer)[2] is reported here from Ontario for the first time. A survey indicated that, during the summer of 1973, the species was generally distributed throughout the southern part of the city of Sudbury. The trees affected were mainly open-grown, ornamental silver maple, *Acer saccharinum L.*, from 8' to 20' high.

Recognizable damage appeared on the new leaves while they were still curled. Affected leaves turned upwards and developed shallow pouch-like distortions on the leaf blades near the veins. About 20% of the infested leaves continued to grow and enlarge but often became distorted and tattered when growth tensions caused ruptures.

When the occurrence was discovered in early July, the size of many of the larvae suggested that first oviposition must have taken place several weeks previously. Although oviposition was not observed, a cluster of unhatched but apparently healthy eggs was located on the upper surface of a partly folded leaf on July 25.

The masses of white or pale cream larvae were found throughout the summer, often mixed instar groups of 20 or more in tightly curled leaves. As the leaves became distorted by the formation of the pouches, the larvae could be found in the crevices between the swellings and the larger veins. Late instar larvae were covered with a dense webbing under which pupation took place (Fig. 1).

From an examination of the available larvae it appeared that this species has either three or four larval instars. The larva is typically cecidomyid (Fig. 2) with an ellipsoidal anterior and a broadly blunt posterior end. In the early instars the

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[2]*Dasineura aceris* (Shimer)—new combination by Dr. R. J. Gagne, U.S.D.A. (U.S.N.M.), Washington, D.C.

setation and spinules are similar to those of the final instar (Fig. 3) but the ventral thoracic spatula consists of a long slender shaft abruptly explanate anteriorly with two acute anterior points. The form of the spatula although variable is quite distinct from that found in other genera. The setal pattern is similar to that of many other cecidomyids, but the ventral spinule fields are quite different from genera like *Mayetiola* in which the spinules are much smaller.

Summer pupation took place in small white cocoons spun in the larval locations on the leaves and usually beneath webbing spun by late instar larvae. Pupae (Fig. 4) were approximately 1.5 mm long. Fully formed individuals appeared dirty white with pitchy grey wing pads of which the margins were darker. On the dorsum of the thorax pairs of pale-brown V-shaped dorsal and sub-dorsal longitudinal bands extend from near the thoracic horns to the mid-dorsal point of the posterior margin. The pupal stage lasts about 10 days. Remnants of pupation consisted of the stained and ruptured cocoon with the partly extruded pupal case.

From the rather preliminary information obtained, *Dasineura aceris,* in the Sudbury area, emerges in the spring and infests the new leaves of silver maple as they begin to uncurl. Throughout the summer the various stages overlap until the leaves are too well developed for further oviposition.

Winter pupation in *D. acericrispans* (K.) in Europe takes place in the soil. Although no evidence of soil pupation could be found in *Dasineura aceris,* it is possible that winter pupation of this species is of this type.

There was no evidence of larval parasitism but small chalcid wasps, *Platygaster* sp., were found emerging from the midge cocoons. These adults emerged through neatly cut round holes, often in the thoracic region of the host.

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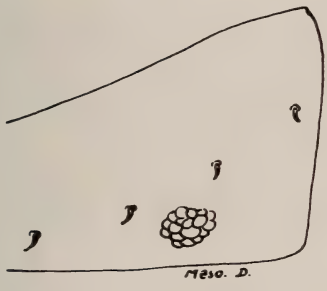

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FIGURE 1. Full-grown larva on leaf, showing characteristic webbing.

FIGURE 2. Larva, ventral view.

FIGURE 3. a) Dorsal, mesothorax; b) dorsal, eighth abdominal segment.

FIGURE 4. Pupa, lateral view.

PHENOLOGY OF CARABID BEETLES OF THUNDER BAY AND THEIR ASSOCIATED MITE POPULATION[1]

D. P. Ostaff[2] and R. Freitag[3]

Abstract

Throughout the summer of 1970, populations of carabid beetles were sampled using pitfall traps in two forested areas. Ten species were caught exclusively in an aspen forest, two species, *Agonum gratiosum* Mann. and *Pterostichus punctatissimus* Rand., exclusively in a black spruce forest and four additional species were found in both areas. Each of the six most predominate species collected exhibited a distinct seasonal occurrence pattern. Nine species of phoretic mites were identified on five of the most numerous beetle species. They appeared on the beetles as adult male or females or in the deutonymph, or hypopi stage. Some such as *Blattisocius keegani* Fox, *Poecilochirus* sp., *Parasitus* sp. and *Glycyphagus domesticus* De Geer were species specific with the host beetle while others, principally *Sancassania (Caloglyphus)* sp. near *spinitarsus* Herman and *Schwiebea* sp. near *scheucharae* Turk and Turk were found on four of the host species. Mites were found equally on both sexes of beetles.

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Introduction

Carabid beetles are found in a wide variety of habitats (Lindroth 1961, 1966, 1969) but more frequently in light deciduous forests or in open meadows on cultivated ground (Lindroth 1961, 1966). Rivard (1964 a;b) studied the occurrence and ecology of carabid beetles in eastern Ontario, and Freitag, Ozburn and Leech (1969) and Freitag and Poulter (1970) studied the effects of sumithion and phosphamidon on populations of five carabid beetles in Northwestern Ontario.

Pitfall traps are well suited for the collection of arthropods at the soil surface, especially Carabidae (Esau 1968). They yield an excellent qualitative method of sampling all active organisms in an area because they operate 24 hours/day, collecting diurnal, crepuscular and nocturnal forms, never selecting for any one species which would skew the results.

Mites are known to form phoretic relationships with various Coleoptera (Chmielewski and Lipa 1967; Hunter 1969; Hunter and Moser 1968). Nickel and Elzinga (1969) investigated a parasitic relationship between a pyemotid mite and carabid beetles. This present paper provides information on the occurrence and phenology of some Carabidae living in an aspen and black spruce habitat near Thunder Bay, Ontario, and the mite population associated with the most common beetles.

Materials and Methods

Pitfall traps, constructed from two-quart milk cartons 12.7 cm deep and 10.2 cm wide, were set into the soil with their top edge level with the soil surface. Twenty-five traps were placed linearly, 4 metres apart in an aspen and black

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spruce habitat. An aluminum pie-plate-roof prevented the entrance of rain and debris. No collecting liquid or bait was used.

Traps were emptied weekly from 9 July to 8 October, with each beetle being individually recorded and preserved in a 4 dram snap cap vial containing 70% ethanol. Each beetle was keyed to genus and species (Lindroth 1961, 66, 69), sexed and examined for mites. The contents of each vial were filtered to trap any dislodged mites. Mites were identified by Dr. E. E. Lindquist.[4]

Results and Discussion

Ten species of carabid beetles were caught exclusively in the aspen habitat and only two species in the black spruce habitat (Table 1). Excess soil moisture decreases activity of ground beetles (Esau 1968) thus making a black spruce-bog community less likely to support a large diversity of species.

During the summer collecting period, of the total population of the six most common beetle species, approximately 34% was collected in July, 54% in August, 9% in September, and 3% during the first two weeks of October (Table 2). Each species exhibited a distinct seasonal occurrence pattern. *Agonum gratiosum,* found only in the black spruce habitat, occurred in late spring and early summer (Table 2). The peak population of *Calathus ingratus* Dejean occurred in mid to late July as also noted by Freitag, Ozburn and Leech (1969) and Freitag and Poulter (1970) (Table 2). *Carabus nemoralis* Müller, the most numerous species collected, emerged in late summer constituting a peak population in mid-August (Table 2). *Pterostichus melanarius* Illiger was trapped throughout the summer, while *P. pensylvanicus* LeConte occurred in early summer, corroborating reports by Freitag and Poulter (1970) (Table 2). *Synuchus impunctatus* Say occurred in late July to early August (Table 2). Each species differed in peak period of activity thereby reducing any competition effects in an environment.

Phoretic mites were attached to the antennae, eyes, pronotum, mouth parts, inter-segmental membranes and all parts of appendages of host beetles. Mites from 5 species of carabid beetles were identified to species (Table 3). Of the nine species identified, members of the family Acaridae were most numerous. Six species of mites were species specific while two, *Sancassania (Caloglyphus)* sp. near *spinitarsus* and *Schwiebea* sp. near *scheucherae* were found on four of the five beetle species studied (Table 3). *C. ingratus* carried 5 mite species, the greatest variety of mites. The hypopi stage, a heavily sclerotized, non feeding stage, was the most common stage of development encountered. However, deutonymphs, adult males, and adult females were also present. The hypopus is resistant to desiccation and is thought to be the stage in which most phoretic mites disperse (Baker and Warton 1959). The occurrence of adult stages could be explained by the presence of putrifying carcasses of beetles in pitfall traps, providing a favorable environment for mite development. Since none of the family Acaridae appears to be either a predator or parasite (Baker and Warton 1959), adult carabid beetles probably serve as dispersal agents for mites, as found for other beetles.

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TABLE 1. Distribution of carabid beetles by habitat and the average no. of phoretic mites of all species collected during the summer of 1970 at Thunder Bay, Ontario.

Habitat	Beetle Species	Total no. of Beetles	Total no. of Phoretic Mites	Ave. no. mites/♂ Beetle	Ave. no. mites/♀ Beetle	Stats[b] on Preference
Aspen	[a]*Agonum decentis* Say	9	31	2.0	3.9	
	[a]*A. mannerheimi* Dejean	3	4	0	2.0	
	A. placidum Say	9	8	1.2	.3	
	A. sordens Kirby	8	18	2.0	2.3	
	A. trigeminum Lindroth	1	5	—	5.0	
	Calathus ingratus	36	34	.4	1.1	N.S.
	Carabus meander Fischer	1	0	—	0	
	C. nemoralis	108	84	.5	1.0	*
	Loricera pilicornis Fabricius	1	1	1.0	—	
	Patrobus longicornis Say	5	17	5.5	2.0	
	[a]*Pterostichus adstrictus* Eschschultz	6	11	.7	3.0	
	[a]*P. melanarius*	40	52	.9	1.6	N.S.
	P. pensylvanicus	19	24	1.7	1.1	N.S.
	Synuchus impunctatus	27	28	1.3	.5	N.S.
Black spruce	*A. gratiosum*	16	18	.5	1.2	
	P. punctatissimus	2	4	0	4.0	
	Totals	291	339	.9	1.4	N.S.

[a]Species occurring in both habitats.
[b]All statistics, t-test. Probability levels: $P<.05$, *; N.S., not significant.

TABLE 2. Weekly collections of the 6 most common carabid beetle species collected in pitfall traps from an aspen and black spruce habitat at Thunder Bay, 1970.

	July				August				September				October		Total	
	9	16	23	30	6	13	20	27	3	10	17	24	1	8	No.	%
Agonum gratiosum[a]	15	0	1	0	0	0	0	0	0	0	0	0	0	0	16	6.8
Calathus ingratus	5	3	12	8	3	3	0	1	1	0	0	0	0	0	36	15.2
Carabus nemoralis	0	0	0	1	0	20	60	8	6	7	0	3	0	4	109	46.2
Pterostichus melanarius	0	6	6	6	4	7	8	1	1	0	0	0	0	0	39	16.5
Pterostichus pensylvanicus	4	7	1	0	0	1	1	0	3	0	0	0	2	0	19	8.0
Synchus impunctatus	0	0	2	7	8	8	1	0	1	0	0	0	0	0	27	7.2
Totals	24	16	22	22	15	39	70	10	12	7	0	3	2	4	246	

[a]The only species collected from the black spruce habitat.

TABLE 3. Family, species and stage of development of mites on five carabid beetles collected weekly from an aspen habitat 9 July to 8 October, 1970, Thunder Bay, Ontario.

Family of Mite	Species of Mite	Associated Carabid Beetle	Stage of Development of Mite
Acaridae	*Tyrophagus putrescentiae*	*Calathus ingratus*	adult male
	Sancassania (=Caloglyphus) sp. near *spinitarsus* Herman	*Calathus ingratus*	hypopi
		Pterostichus melanarius	hypopi
		P. pensylvanicus	hypopi
		Synuchus impunctatus	hypopi
	Acotyledon sp. near *schmitizi* Oudemans	*Pterostichus pensylvanicus*	hypopi
		Synuchus impunctatus	hypopi
	Schwiebea sp. near *scheucherae* Turk and Turk	*Calathus ingratus*	hypopi
		Carabus nemoralis	hypopi
		Pterostichus pensylvanicus	hypopi
		Synuchus impunctatus	hypopi
Ascidae	*Blattisocius keegani* Fox	*Calathus ingratus*	adult female
Parasitidae	*Poecilochirus sp.*	*Carabus nemoralis*	deutonymph
	Parasitus sp.	*Pterostichus melanarius*	adult female, deutonymph
Glycyphagidae	*Glycyphagus domesticus* De Geer	*Calathus ingratus*	adult female
Anoetidae	genus undetermined	*Carabus nemoralis*	hypopi

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AN ANNOTATED LIST OF ARTHROPODS COLLECTED FROM RING-BILLED GULL NESTS ON GRANITE ISLAND, BLACK BAY, LAKE SUPERIOR, 1972 AND 1973

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Abstract

An annotated list of names is given of arthropods collected from ring-billed gull *Larus delawarensis* Ord nests.

* * * * * *

The foremost check-lists of insects in bird nests have been compiled by Hicks (1959, 1962); they include 18 orders of insects, 26 orders of birds, an ornithological check-list, and pertinent citations up to 1962. References to observations of insects in larid nests comprise 15 species. However, no account is given on nest inhabitants of the ring-billed gull *Larus delawarensis* Ord.

The work upon which the following list of names and other papers (Freitag *et al,* 1974; and Ryder and Freitag, 1974) is based was carried out during the summer and winter of 1972 and the summer of 1973. Nests of ring-billed gulls on Granite Island, 48° 43' N. 88° 29' W., were examined first for arthropods specifically in relation to chick mortality. In subsequent investigations fluctuations in the nest mite populations were observed to follow closely the breeding cycle of the gulls (Freitag *et al,* 1974). Also moisture and nest size were found to govern the density of the arthropod populations in general. During the course of these studies approximately 26,000 arthropods were removed from sixty-nine gull nests. Details of the collecting methods and treatment of material have been described elsewhere (Ryder and Freitag, 1974).

The list below contains names of almost all of the collected arthropods. A few immature forms remain unidentified and have been excluded. While determinations to species were made whenever possible, specimens of groups which require taxonomic revision or damaged specimens were identified to genus. Except for orders, which are arranged according to tradition, families, genera, and species are in alphabetical order. An asterisk following a name indicates that the taxon has been observed in nests of birds other than ring-billed gulls (see Hicks 1959, 1962, for bird names and references). Remarks by the systematists, who identified the specimens have been altered slightly to suit the list.

Order Pseudoscorpiones

Cheliferidae

Chelifer Sp.

Order Opiliones

genus undetermined

Order Araneida

Araneidae

Aranea Sp. (immature)

Clubionidae

Clubiona Sp. (immature)

Dictynidae

Dictyna manitoba Ivie. N.W.T. to Ontario and into U.S.A.
Dictyna minuta Emerton

Drassidae (Gnaphosidae)

Micaria Sp. (immature)
Zelotes Sp. (immature)

Erigonidae

Eridantes erigonoides (Emerton). This species has been collected in sweeping bushes and grasses, from debris along salt marshes and that brought down by early spring floods. Found mainly in New England, Eastern U.S. and Canada.

Gonatium rubens (Blackwell). This species has been collected from bushes and under fallen leaves. Holarctic, northern and boreal mainly.

Hahniidae

Neoantistea Sp. (immature)

Lycosidae

Pardosa Sp. (immature)
Trochosa terricola Thorell

Salticidae

genus undetermined

Thomisidae

Philodromus Sp. (immature) Likes warm, dry places.
Philodromus cespitum (Walckenaer)

Order Acarina

Acaridae

Tyrophagus mixtus Volgin

Ameroseiidae

Ameroseius corbicula (Sowerby)

Anystidae

Anystis Sp.

Ascidae

Lasioseius confusus Evans

Astegistidae

Furcoribula Sp.

Bdellidae

Bdella longicornis (Linnaeus)

Belbodamaeidae

Belbodamaeus Sp.

Bryobiidae

Petrobia latens (Müller)

Camisiidae

Platynothrus peltifer (Koch)

Carabodidae

Carabodes Sp. near *areolatus* Berlese

Ceratozetidae

Diapterobates Sp.
Trichoribates Sp.

Damaeidae

Epidamaeus Sp.

Digamasellidae

Digamasellus reticulosus (Hirschmann)

Eremaeidae

Eremaeus Sp.

Erythraeidae

Abrolophus Sp.
Balaustium Sp.
Bochartia Sp.
Erythraeus Sp.
Leptus Sp.

Galumnidae

Galumna Sp.

Haplozetidae

Peloribates Sp.
Xylobatis Sp.

Laelapidae

Hypoaspis austriaca Sellnick
Hypoaspis Sp. near *giffordi* Evans and Till
Laelaspis dubitatus Hunter
Ololaelaps hemisphaera (Berlese)
Olalaelaps veneta (Berlese)
Pseudoparasitus Sp.

Liacaridae

Adoristes Sp.
Liacarus (Dorycranosus) Sp.

Macrochelidae

Macrocheles Sp. near *browningi* Evans and Hyatt
Macrocheles glaber (Müller)

Nothridae

Nothrus Sp.

Oppiidae

Oppia Sp.

Orbatulidae

Oribatula Sp.
Scheloribates Sp. near *pallidulus* (Koch)
Zygoribatula Sp.

Pachylaelapidae

Pachylaelaps Sp. near *brevicrinitus* Hirschmann

Parakalumnidae
Neoribates Sp.

Parasitidae
Parasitus fimetorum (Berlese)
Parasitus numerus Karg.

Pelopidae
Peloptulus Sp.

Phthiracaridae
genus undetermined

Tectocepheidae
Tectocepheus Sp.

Trhypochthoniidae
Trhypochthonius Sp. near *tectorum* (Berlese)

Trombidiidae
Microtromidium Sp.

Uropodidae
Apionoseius Sp.
Uropoda Sp.

Order Collembola

Entomobryidae
*Entromobrya** Sp.
Entombryoides pupurascens (Packard)
*Willowsia buskii** (Lubbock)

Isotomidae
*Isotoma** Sp. Probably *violacea* Tullbug
*Isotoma viridis** Bourlet. As currently defined this is probably a complex in Canada.

Poduridae
*Hypogastrura** Sp. Almost certainly *armata* (Nicolet)

Sminthuridae
*Sminthurides** Sp. Probably *occultus* Mills

Order Psocoptera

One nymphal psocoptera
genus undetermined

Order Thysanoptera

Phlaeothripidae
Liothrips Sp. The genus *Liothrips* contains about 50 North and Middle American described species. Most species are phytophagous and the majority are host-specific. This specimen resembles *L. usitatus* Hood which occurs on *Rhus copallina*. However it differs from this species in several characteristics (wing and antennal color).

Megathrips lativentris (Heeger). This species is holarctic or was introduced from Europe into North America. It is a fungus feeder and is usually found in leaf litter. It's been reported from Ontario, New England, Minn, Ill. and Colorado. Two other species in this genus occur in California.

Nesothrips bicolor (Heeger). Apterous. This species occurs in Europe and Eastern North America where it is said to have been introduced. It usually occurs in grass tussocks.

Thripidae

Anaphothrips Uzel. It is very common to *A. cameroni* (Bagnall) a common, grass-inhabiting species of boreal N. America. But, it differs in several characteristics (color too yellow, chaetotaxy of abdominal segment VIII and IV too long) from Alberta and B.C. specimens.

Anaphothrips obscurus (Muller). The grass thrips. This is a very common, holarctic grass feeder. Males are unknown and females occasionally become pests on corn and other cereals.

Aptinothrips stylifer Trybom. Apterous. This is a very common grass thrip with a holarctic distribution. In Europe males are sometimes found, here it is parthenogenetic. It resides all over Alberta including above the treeline in the Rockies. Farther south it is replaced by *A. rufus* (Gmellin) which sometimes becomes a pest of cereals.

Baliothrips dispar (Haliday). Macropterous. This is a north temperate holarctic species found on grasses. It exhibits wing polymorphism in both sexes (macroptery and microptery).

Order Homoptera

Aphididae

Immature and parasitized specimen of a grass feeding aphid probably *Holcaphis freguens* (Walker). This aphid feeds in the bases of rolled leaves.

Cicadellidae

Agallia quadripunctata (Prov.)

Lygaeidae

genus undetermined

Pseudococcidae

Phenacoccus Sp. or *Pseudococcus** Sp.

Order Coleoptera

Carabidae

*Metabletus** *americanus* Dej.

Cryptophagidae

*Anchicera** Sp.

Curculionidae

Listronotus Sp. Adults occur on various subaquatic plants such as *Carex, Sagittaria, etc.* Also found on mud or sand along lake and pond margins.

Elateridae

*Melanotus** *leonardi* LeC.

Lathridiidae

*Melanophthalma** Sp.

Leiodidae

Agathidium Sp.

Leptodiridae

*Catops** Sp.

Nitidulidae

Omosita colons L.

Orthoperidae

*Orthoperus** Sp.

Ptiliidae

genus undetermined

Staphylinidae

Hypnogrus Sp.
*Oligota** Sp.
*Philonthus** Sp.
*Platystethus** *americanus* Er.

Tachyporus jocosus Say. Genus soon revised and this name will probably be changed.

*Tachyporus nitidulus** (Fab.)

Order Lepidoptera

Elachistidae

Elachista Sp. Probably a grass feeder.

Pyralididae

Phlyctaenia sambuculis Schiff

Tineidae

genus undetermined

Tortricidae

Exartema Sp.

Order Diptera

Anthomyiidae

Hylemyia platura Mg. Larvae are root maggots

Cecidomyiidae

genus undetermined. These gall midges are probably associated with plant material in or adjacent to the nest. It is virtually certain they would have no effect on nestlings.

Chironomidae

Paraphaenocladius exagitans (Johannsen)

Smittia Probably new species: at least this species has not been recorded from North America. Many species of this genus have been described in Europe; however, the genus needs revision before specific comparisons can be made.

Chloropidae

Gaurax melanotum Sabrosky
*Oscinella** *near umbrosa* (Leow.)
Siphonella prob. *setulosa* Mall.
Siphonella Sp. tenera

Dixidae

Dixa Sp. Larvae are aquatic in freshwater

Ephydridae

Scatella picea (Walk)

Lauxaniidae

*Minettia** *lupulina* (Fab.)

Milichiidae

*Leptometopa** Sp. prob. *rufifrons* Becker. Members of this genus are often found in birds nests, larvae probably live in excrement and decaying organic matter.

Muscidae

*Muscina assimilis** (Fallen) Common filth inhabiting fly.

Scatopsidae

*Scatopse fuscipes** Meigen

Sciaridae

*Bradysia** Sp.

Sphaeroceridae

*Leptocera** Sp.
*Sphaerocera pusilla** (Fallen)

Order Hymenoptera

Aphelinidae

Aphelinus near *mali* Haldeman

Braconidae

*Apanteles** Sp. These are parasites of lepidopteran larvae and the groups to which this specimen belongs attack macrolepidopterans. It is probably only an accident.

Ceraphronidae

Conostigmus Sp. Primary parasites of higher Diptera (Brachycera). Thus this genus is relevant to gull's nest fauna.

Chalcididae

*Asaphes vulgaris** Walker.

Cynipidae

*Kleidotoma** Sp.

Diapriidae

*Trichopria** Sp. Are primarily parasites of higher Diptera (Brachycera). This genus is thus relevant to gull's nest fauna.

Eulophidae

Elachertus Sp. Possibly new species.
*Necremnus** *californicus* (Girault).

Eupelmidae

Eupelmella vesicularis (Retzius).

Figitidae

Figites Sp.

Formicidae

Leptothorax (Mychothorax) canadensis Prov. Is widely distributed in wooded areas, such as basswood-maple forest, tamarack bog, spruce-fir forest or aspen forest. It usually forms small colonies in galleries and chambers in decaying logs and stumps, or it may inhabit sites under rock, in peat, sand, clay or loam.

*Myrmica** *emeryana* Forel. Prefers damp and shady habitats and may be found in forest situations similar to those listed for *L. canadensis* or it may also be found in grass-lands or meadows. Its nests are commonly found under wood, stones, cowdung or leaf-mould. *L. canadensis* and *M. emeryana* have also been found together in nests in rotten branches lying on the ground.

Ichneumonidae

Dicaelotus Sp. (Phaeogenini). Members of this genus have been reared from Gelechiidae (microlepidoptera).

Stibeutes Sp. Parasite of muscoid Diptera.

Pteromalidae

*Spalangia drosophilae** Ashmead.

Scelionidae

*Telenomus** Sp.

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CARABID BEETLES OF ANTICOSTI ISLAND, QUEBEC

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Abstract

A list of carabid beetles of Anticosti Island, Québec is given, which includes 83 species.

* * * * * *

Only 18 species of carabid beetles have been recorded previously from Anticosti Island (Lindroth, 1956, 1961, 1963, 1966, 1968 and 1969; Larochelle, 1972). The list below provides an additional 65 species found on the Island.

I wish to give sincere thanks to the officers of the Consolidated Bathurst Company and to the Ministère des Terres et Forêts du Québec, who made it possible for me to make this study.

The sources of the material included are: (1) Specimens preserved in the following collections—Canadian National Collection, Ottawa (CNC); Jean-Paul Laplante Collection, Sainte-Foy, Québec (JPL); Laboratoire des Recherches Forestières, Sainte-Foy, Québec (LRF); Museum of Comparative Zoology, Cambridge, Massachusetts (MCZ). (2) Published records given in the references that follow the list. (3) My own collecting from July 12 to 18, 1971; the collection of species included in this material has been deposited in the Terres et Forêts du Québec Collection (TFQ) and in the author's collection (AL). In order to save space the ecology of the species is not given.

The following list includes 83 species.

List of Species

Sphaeroderus nitidicollis Chevrolat, Rivière au Bec-Scie (1, JPL); Rivière Jupiter (2, AL; 14, TFQ); Rivière McDonald (1, AL); Rivière à la Patate (2, AL; Larochelle, 1972).

Carabus maeander Fischer. Exact place unrecorded (MCZ; Lindroth, 1961).

Carabus serratus Say. Rivière Jupiter (1, AL).

Nebria gyllenhali Schönherr. Port-Menier (2, AL; 27, TFQ); Rivière Jupiter (2, AL; 17, TFQ).

Notiophilus semistriatus Say. Baie-Sainte-Claire (1, AL); Rivière à la Patate (2, AL; 1, TFQ).

Notiophilus aquaticus Linné. Rivière à la Patate (2, AL; 2, TFQ); Rivière Vauréal (2, AL; 1, TFQ).

Blethisa multipunctata Linné. Port-Menier (2, AL).
Elaphrus americanus Dejean. Port-Menier (2, AL; 9, TFQ).

Loricera pilicornis Fabricius. Exact place unrecorded (MCZ; Lindroth, 1961); Port-Menier (2, AL; 9, TFQ).

Clivina fossor Linné. Exact place unrecorded (1, LRF); Baie-Sainte-Claire (1, AL); Port-Menier (2, AL; 6, TFQ); Rivière à l'Huile (2, AL; 3, TFQ); Rivière Jupiter (1, AL).

Miscodera arctica Paykull. Rivière à la Patate (1, AL).

Patrobus lecontei Chaudoir. Port-Menier (2, AL).

Patrobus stygicus Chaudoir. Exact place unrecorded (1, JPL; MCZ; Lindroth, 1961); Port-Menier (2, AL).

Trechus crassiscapus Lindroth. Port-Menier (1, AL).

Trechus apicalis Motschoulsky. Exact place unrecorded (MCZ; Lindroth, 1963); Port-Menier (1, AL); Rivière à l'Huile (1, AL); Rivière Jupiter (2, AL; 3, TFQ); Rivière McDonald (2, AL); Rivière Vauréal (2, AL).

Bembidion levettei Casey. Port-Menier (1, AL).

Bembidion rusticum Casey. Rivière à l'Huile (2, AL; TFQ); Rivière McDonald (1, AL); Rivière à Patate; Rivière Vauréal (2, AL; 4, TFQ).

Bembidion sulcipenne prasinoides Lindroth. Rivière Jupiter (2, AL; 1, TFQ); Rivière à la Patate (2, AL; 11, TFQ); Rivière Vauréal (2, AL).

Bembidion carolinense Casey. Rivière à l'Huile (2, AL; 8, TFQ); Rivière Jupiter (2, AL; 5, TFQ); Rivière McDonald (2, AL; 3, TFQ); Rivière à la Patate (2, AL; 11, TFQ); Rivière Vauréal (1, AL).

Bembidion concolor Kirby. Rivière à l'Huile (2, AL); Rivière McDonald (1, AL); Rivière Vauréal (1, AL).

Bembidion grapei Gyllenhal. Exact place unrecorded (2, JPL).

Bembidion bruxellense Wesmael. Exact place unrecorded (4, CNC; Lindroth, 1963; Port-Menier (2, AL; 12, TFQ).

Bembidion transversale Dejean. Port-Menier (2, AL; 8, TFQ); Rivière à l'Huile (1, AL); Rivière Jupiter (2, AL); Rivière à la Patate (2, AL; 1, TFQ); Rivière Vauréal (2, AL; 9, TFQ).

Bembidion scopulinum Kirby. Exact place unrecorded (MCZ; Lindroth, 1956 and 1963); Port-Menier (2, AL; 9, TFQ); Rivière à l'Huile (2, AL; 10, TFQ); Rivière Jupiter (2, AL; 5, TFQ); Rivière McDonald (2, AL; 1, TFQ); Rivière à la Patate (2, AL; 7, TFQ); Rivière Vauréal (2, AL; 19, TFQ).

Bembidion incrematum Leconte. Rivière à l'Huile (1, AL).

Bembidion nigripes Kirby. Exact place unrecorded (MCZ; Lindroth, 1963); Port-Menier (2, AL; 9, TFQ); Rivière à l'Huile (1, AL); Rivière Vauréal (1, AL).

Bembidion versicolor Leconte. Rivière à l'Huile (1, AL); Rivière Vauréal (1, AL).

Bembidion quadrimaculatum oppositum Say. Rivière Jupiter (1, AL).

Bembidion transparens Gebler. Port-Menier (2, AL).

Bembidion concretum Casey. Port-Menier (2, AL; 2, TFQ).

Bembidion forestriatum Motschoulsky. Rivière Vauréal (2, AL; 2, TFQ).

Bembidion wingatei Bland. Exact place unrecorded (MCZ; Lindroth, 1963); Baie-Sainte-Claire (1, AL); Rivière Jupiter (1, AL); Rivière McDonald (1, AL); Rivière Vauréal (1, AL).

Pterostichus lucublandus Say. Baie-Sainte-Claire (2, AL); Rivière à l'Huile (2, AL; 1, TFQ).

Pterostichus adstrictus Eschscholtz. Exact place unrecorded (CNC; 1, LRF; Lindroth, 1966); Baie-Sainte-Claire (2, AL); Port-Menier (2, AL; 10, TFQ); Rivière à l'Huile (2, AL; 1, TFQ); Rivière Jupiter (2, AL; 15, TFQ); Rivière McDonald (2, AL; 12, TFQ); Rivière à la Patate (2, AL; 16, TFQ); Rivière Vauréal (2, AL; 10, TFQ).

Pterostichus pensylvanicus Leconte. Port-Menier (1, AL); Rivière McDonald (2, AL; 2, TFQ).

Pterostichus melanarius Illiger. Baie-Sainte-Claire (2, AL; 30, TFQ); Port-Menier (2, AL; 28, TFQ); Rivière à l'Huile (2, AL).

Pterostichus coracinus Newman. Exact place unrecorded (1, CNC; MCZ; Lindroth, 1966); Baie-Sainte-Claire (2, AL; 9, TFQ); Port-Menier (2, AL; 35, TFQ); Rivière Jupiter (2, AL; 20, TFQ); Rivière McDonald (2, AL; 10, TFQ); Rivière à la Patate (2, AL; 3, TFQ); Rivière Vauréal (2, AL; 2, TFQ).

Pterostichus caudicalis Say. Exact place unrecorded (MCZ; Lindroth, 1966); Port-Menier (2, AL; 1, TFQ); Rivière Jupiter (1, AL).

Pterostichus luctuosus Dejean. Baie-Sainte-Claire (1, AL); Port-Menier (1, AL).

Pterostichus patruelis Dejean. Baie-Sainte-Claire (2, AL); Port-Menier (2, AL; 7, TFQ); Rivière Vauréal (2, AL; 1, TFQ).

Pterostichus punctatissimus Randall. Exact place unrecorded (2, CNC; Lindroth, 1966); Baie-Sainte-Claire (2, AL; 4, TFQ); Port-Menier (2, AL; 1, TFQ); Rivière Jupiter (2, AL; 5, TFQ).

Calathus ingratus Dejean. Exact place unrecorded (MCZ; Lindroth, 1966); Port-Menier (2, AL; 19, TFQ); Rivière à l'Huile (2, AL; 3, TFQ); Rivière Jupiter (2, AL; 1, TFQ); Rivière McDonald (2, AL; 10, TFQ); Rivière à la Patate (2, AL; 11, TFQ); Rivière Vauréal (2, AL; 11, TFQ).

Calathus advena Leconte. Port-Menier (2, AL; 17, TFQ); Rivière McDonald (2, AL); Rivière Vauréal (1, AL).

Synuchus impunctatus Say. Port-Menier (1, AL); Rivière à l'Huile (1, AL); Rivière McDonald (1, AL).

Agonum quadripunctatum Lindroth. Port-Menier (1, AL).

Agonum picicornoides Lindroth. Port-Menier (1, AL).

Agonum gratiosum Mannerheim. Rivière à l'Huile (2, AL; 1, TFQ).

Agonum thoreyi Dejean. Port-Menier (2, AL; 6, TFQ).

Agonum nigriceps Leconte. Port-Menier (1, AL).

Agonum cupripenne Say. Rivière Jupiter (1, AL).

Agonum muelleri Herbst. Exact place unrecorded (MCZ; Lindroth, 1966); Baie-Sainte-Claire (1, AL); Port-Menier (2, AL; 23 TFQ); Rivière à l'Huile (2, AL; 4, TFQ); Rivière Jupiter (2, AL; 6, TFQ); Rivière McDonald (2, AL; 12, TFQ).

Agonum affine Leconte. Baie-Sainte-Claire (2, AL; 4, TFQ).

Agonum metallescens Leconte. Baie-Sainte-Claire (1, AL); Port-Menier (2, AL; 19, TFQ); Rivière à l'Huile (1, AL).

Agonum propinquum Gemminger and Harold. Port-Menier (2, AL; 7, TFQ).

Agonum placidum Say. Rivière à l'Huile (1, AL).

Agonum decentis Say. Port-Menier (1, AL); Rivière à l'Huile (1, AL); Rivière Jupiter (2, AL; 1, TFQ); Rivière McDonald (2, AL); Rivière à la Patate (2, AL; 1, TFQ).

Amara torrida Panzer. Exact place unrecorded (1, CNC; Lindroth, 1968); Port-Menier (2, AL; 14, TFQ); Rivière à l'Huile (2, AL; 1, TFQ).

Amara apricaria Paykull. Port-Menier (1, AL); Rivière à l'Huile (2, AL; 3, TFQ).

Amara quenseli Schönherr. Port-Menier (1, AL); Rivière à l'Huile (2, AL; 6, TFQ); Rivière Jupiter (2, AL; 6, TFQ); Rivière à la Patate (2, AL; 4, TFQ); Rivière Vauréal (2, AL; 19, TFQ).

Amara bifrons Gyllenhal. Port-Menier (2, AL; 4, TFQ); Rivière Jupiter (2, AL; 3, TFQ); Rivière Vauréal (1, AL).

Amara sinuosa Casey. Port-Menier (1, AL).

Amara laevipennis Kirby. Exact place unrecorded (CNC; Lindroth, 1963; Rivière Jupiter (1, AL).

Amara lunicollis Schiödte. Rivière à l'Huile (1, AL); Rivière Vauréal (1, AL).

Amara littoralis Mannerheim. Rivière à l'Huile (1, AL).

Amara cupreolata Putzeys. Baie-Sainte-Claire (2, AL); Port-Menier (2, AL; 8, TFQ).

Harpalus rufipes De Geer. Port-Menier (2, AL; 13, TFQ); Rivière à l'Huile (2, AL; 13, TFQ); Rivière Jupiter (2, AL; 4, TFQ); Rivière à la Patate (2, AL; 2, TFQ); Rivière Vauréal (2, AL; 19, TFQ).

Harpalus affinis Schrank. Port-Menier (2, AL; 10, TFQ); Rivière à l'Huile (2, AL; 34, TFQ); Rivière Jupiter (2, AL; 3, TFQ); Rivière à la Patate (6, AL; 9, TFQ).

Harpalus laticeps Leconte. Port-Menier (1, AL); Rivière Jupiter (2, AL; 1, TFQ).

Harpalus egregius Casey. Exact place unrecorded (MCZ; Lindroth, 1968).

Harpalus fulvilabris Mannerheim. Port-Menier (2, AL; 2, TFQ); Rivière à l'Huile (2, AL; 4, TFQ); Rivière Jupiter (2, AL; 1, TFQ); Rivière McDonald (1, AL); Rivière à la Patate (2, AL; 3, TFQ); Rivière Vauréal (1, AL).

Harpalus pleuriticus Kirby. Rivière à l'Huile (2, AL; 9, TFQ); Rivière Jupiter (2, TFQ).

Harpalus fuliginosus Duftschmid. Baie-Sainte-Claire (1, AL); Rivière à l'Huile (1, AL); Rivière Jupiter (2, AL; 19 TFQ); Rivière McDonald (1, AL); Rivière à la Patate (2, AL; 1, TFQ); Rivière Vauréal (2, AL; 2, TFQ).

Trichocellus cognatus Gyllenhal. Port-Menier (2, AL; 4, TFQ); Rivière Jupiter (1, AL); Rivière Vauréal (2, AL; 14, TFQ).

Bradycellus lecontei Csiki. Port-Menier (2, AL; 2, TFQ).

Bradycellus neglectus Leconte. Rivière à l'Huile (2, AL); Rivière Jupiter (2, AL; 1, TFQ); Rivière Vauréal (2, AL).

Stenolophus fuliginosus Dejean. Port-Menier (1, AL).

Diplocheila striatopunctata Leconte. Port-Menier (2, AL).

Diplocheila obtusa Leconte. Baie-Sainte-Claire (2, AL; 1, TFQ); Port-Menier (1, AL); Rivière Jupiter (2, AL; 1, TFQ); Rivière à la Patate (1, AL).

Badister obtusus Leconte. Baie-Sainte-Claire (1, AL); Rivière à l'Huile (1, AL); Rivière Jupiter (2, AL; 2, TFQ); Rivière à la Patate (2, AL).

Chlaenius pensylvanicus Say. Port-Menier (2, AL; 2, TFQ).

Chlaenius lithophilus Say. Rivière à l'Huile (2, AL); Rivière Vauréal (1, AL).

Metabletus americanus Dejean. Rivière Jupiter (1, AL); Rivière Vauréal (1, AL).

Cymindis cribricollis Dejean. Baie-Sainte-Claire (2, AL; 2, TFQ); Rivière à l'Huile (2, AL; 1, TFQ); Rivière Jupiter (1, AL); Rivière McDonald (1, AL); Rivière à la Patate (2, AL; 5, TFQ).

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NOTES ON THE MATING PERIODS OF SOME CARABID BEETLES (COLEOPTERA : CARABIDAE)

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Abstract

Mating periods are given for twenty-three species of carabid beetles from Québec and Ontario.

* * * * * *

The majority of Canadian Carabidae apparently mate in spring. From April to June 1973, some friends and I observed, in the field and in captivity, mating pairs of 23 species of carabid beetles from southern Québec and Hawkesbury, southeastern Ontario. The following is a list of the mating pairs, with dates and numbers.

Species Accounts

Agonum extensicolle Say: Rigaud, June 15, in captivity, a pair (A. Larochelle and J.-P. Pilotte).

Amara aenea De Geer: Dollard-des-Ormeaux, June 3, in captivity, a pair (J.-P. Tchang). Pointe-aux-Trembles, May 5 and 27, in the field, two pairs (P. Cloutier).

Anisodactylus harrisi Leconte: Rigaud, April 19 to 30, in captivity, three pairs.

Anisodactylus sanctaecrucis Fabricius: Hawkesbury, May 13 and 15, in the field and in captivity, two pairs (F. Dubé).

Anisodactylus verticalis Leconte: Beaconsfield, June 6, in captivity, a pair (F. Marcotte).

Anisotarsus terminatus Say: Beaconsfield, June 6, in captivity, a pair (F. Marcotte).

Calosoma calidum Fabricius: Rigaud, May 31, in captivity, two pairs.

Carabus nemoralis Müller: Montréal, April 19, in captivity, three pairs (J.-P. Lebel). Rigaud, April 24 to May 3, in captivity, three pairs (A. Larochelle and J.-P. Pilotte). Saint-Eustache, June 9, in captivity, a pair (P. Duval).

Chlaenius emarginatus Say: Rigaud, May 31 to June 6, in captivity, eight pairs.

Chlaenius sericeus Forster: Dollard-des-Ormeaux, June 2 to 6, in captivity, eight pairs (F. Marcotte and J.-P. Tchang). Rigaud, May 7 to 27, in captivity, four pairs.

Chlaenius tomentosus Say: Rigaud, May 30 and June 7, in captivity, two pairs.

Harpalus affinis Schrank: Dollard-des-Ormeaux, June 2, in captivity, a pair (J.-P. Tchang). Rigaud, May 14 and June 1, in the field, two pairs.

Harpalus bicolor Fabricius: Rigaud, May 3, in the field, a pair (P. Cloutier).

Harpalus herbivagus Say: Hudson, April 15, in the field, a pair.

Harpalus lewisi Leconte: Rigaud, June 20 to 22, in captivity, three pairs.

Omophron americanum Dejean: Rigaud, April 19 to May 1, in captivity, three pairs.

Pterostichus lachrymosus Newman: Rigaud, May 25 to June 9, in captivity, three pairs.

Pterostichus luctuosus Dejean: Rigaud, May 25, in the field, a pair (A. Larochelle et J.-P. Pilotte).

Pterostichus lucublandus Say: Dollard-des-Ormeaux, June 2, in captivity, two pairs (J.-P. Tchang). Rigaud, May 5 to June 1, in the field and in captivity, five

pairs (A. Larochelle, F. Dubé and J.-P. Tchang). Saint-Sulpice, June 10, in the field, a pair (F. Liard).

Pterostichus pensylvanicus Leconte: Rigaud, April 29, in the field, two pairs (A. Larochelle and P. Cloutier).

Sphaeroderus canadensis Chaudoir: Rigaud, May 3 to 24, in the field and in captivity, twenty-one pairs.

Sphaeroderus lecontei Dejean: Rigaud, May 3 to 7, in the field and in captivity, eight pairs.

Stenolophus conjunctus Say: Rigaud, April 22, in the field, a pair.

Acknowledgments

I am grateful to the following persons who made data available for this study: Pierre Cloutier, Francis Dubé, Paul Duval, Jean-Pierre Lebel, François Marcotte, Jean-Pierre Pilotte, and Jean-Pierre Tchang.

III. THE SOCIETY

GREETINGS FROM THE ENTOMOLOGICAL SOCIETY OF CANADA AND FROM THE ENTOMOLOGICAL SOCIETY OF QUEBEC[1]

Conveyed by D. Keith McE. Kevan

Macdonald Campus, McGill University

Mr. President, Ladies and Gentlemen,

It gives me great pleasure to bring you the greetings of the Entomological Society of Canada. This, as you know, developed in its present form from our Society, which, in 1863, also bore initially the same name, changed to the Entomological Society of Ontario for reasons of political expediency a century ago.

It had been my intention to bring these greetings to you whilst still President of the Entomological Society of Canada, but the timing of annual meetings precluded this. I therefore represent, at his request, my successor, Dr. John McLintock. Dr. McLintock regrets his inability to attend this meeting in person owing to a commitment to attend the Annual Meeting of the Entomological Society of Mani-

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[1]Presented at the 110th Annual Meeting, Entomological Society of Ontario, Kingston, Ontario, Oct. 31-Nov. 2, 1973.

toba, which takes place simultaneously with our own. He nevertheless sends his best wishes on behalf of the Entomological Society of Canada for a most successful meeting at Kingston.

I have also been asked by the President of the Montreal Branch of the Entomological Society of Quebec, Mr. J.-A. Cardinal, to bring you (and Kingston) special greetings on the occasion of the Branch's own centennial. Having formed a branch of the Entomological Society of Ontario from 1873 until 1951 (when it separated to form the nucleus of the Entomological Society of Quebec on the establishment of the present National Society), it has very special ties with us. The (now) Past President of La Société Entomologique du Québec, Dr. Rodolphe

Paradis, also sends cordial centennial salutation from that Society. Being a member of all four groups places me in the very favorable position of being able to gallop off in four directions at once for the purpose of mutual back-slapping!

As this is an historic occasion in more ways than one, you may be interested, and perhaps surprised, to learn that the first entomological society to be formed in Canada was *not,* as you may have fondly imagined, the original E.S.C. (now E.S.O.), born in London, Ontario, 1863, but La Sociéte Entomologique du Bas Canada, set up locally on an informal basis by William Couper and some friends at Rouge near the city of Québec in 1862. This was the same year as the establishment of the oldest (regional) society in the United States — the American Entomological Society of Philadelphia. Unlike this and the E.S.C. (E.S.O.), the activities of the old Quebec group were interrupted from time to time until the establishment of the Montreal Branch in 1873.

In bringing you these felicitations from your sister societies, and finding myself in my present position, I was uncertain whether I was expected to sing for my supper. It therefore occurred to me that you might be entertained to hear a few snatches of insect verse, specifically in relation to my own "pet" group, the orthopteroids (or "grigs" to return to a perfectly good old word that has fallen into disuse). In keeping with the spirit of Kingston's tercentenary, the Entomological Society of Quebec's centennial and a hundred years of the name Entomological Society of Ontario, the verses, so far as possible, are more or less relevant to each hundred years of Canada's history subsequent to the coming of Europeans. I omit the 10th-14th centuries, not because there is no appropriate verse from this period, but because our early tourist visitors, Bjarni Herjolfson and Leif Erikson (son of early communist leader Erik the Red) with their Norse adventurers, as well as compatriots who followed later, were undoubtedly insufficiently cultured to be familiar with it. I restrict my offerings to Caucasian culture, not out of disrespect for the aboriginal Canadians, but because, although they have folklore about Orthoptera and other insects, I know of no appropriate verse in Amerindian or Inuit tongues, let alone any from before "European" times.

The first Europeans to visit Canada for whom there are precise records were, of course, Giovanni Caboto or ("John Cabot") and his companions, who reached our easternmost seaboard in 1497. Although he was an Italian, Caboto came to Canada from Great Britain and it is, therefore, quite possible that, being a man of some education, he may have been familiar with the writings of his contemporary, John Skelton. This poet, probably just prior to Cabot's expedition and nearly 500 years ago, wrote a poem, called *Phylyp Sparowe,* about the demise of a pet bird (which had "fleas blake") belonging to a lady called Jane Scroupe. She bemoaned her loss thus:

.....
Some tyme he wolde gaspe
Whan he sawe a waspe.
A fly or a gnat,
He wolde fly at that
And prytely he wolde pant
Whan he saw an ant.
Lord, how he wolde pry
After the butterfly.
Lorde, how he wolde hop
After the gresshop [grasshopper].

Jacques Cartier's landings in 1534 and subsequently do not fit into our centennial pattern. We can, however, scarcely ignore such an event and, out of deference to Caboto's origin, we might perhaps be forgiven for introducing a fragment from a long Italian poem. One version of this may well have come to the notice of Cartier, for it was first published in 1516 and then, in a revised form, in 1532, just prior to his first visit to Canada. Most educated men of that day knew some Italian. The poem is *Orlando Furioso* by Lodovico Ariosto, who, at the end of the 77th stanza of Canto 35 wrote:

Then heard he the crickets' songs like the verses
The servant in his master's praise rehearses.[1]

By 1573, 400 years ago, there was still no permanent European settlement in Canada, although the Newfoundland fishing industry was well established (the English colony was established in 1583). A little later, Sir Martin Frobisher reached Baffin Island (1576), and Sir Francis Drake claimed New Albion (which included present Washington State and by implication, adjacent territories, i.e., southern British Columbia) for England (1578). French fur-trading posts existed on the lower St. Lawrence, however, and some of the more educated of those concerned may have been aware of the long pastoral poem by Remi Belleau, *La Bergerie* ("The Sheepfold"), first published in 1572. In the section "*l'Esté* (i.e., *l'Eté,* or "Summer") are passages on *"cigales"* which may be translated as follows:

.....
The cigale sings; the swiftly running streams
Entice the shepherds as in humble prayer, it seems,
With murmur sweet, to bathe in waters clean;
Let apples fall from off the branches green,
.....

(and much further on)

.....
Thyme, penny-royal, I've tasted honey from the bees;
To me the Cigale's sound in the elm trees
And all the sweetness that in heaven's prepared,
Cannot, with thy song, my Fair One, be compared.

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[1]This is the translation by Sir John Harrington, 1591, from the part called "The Lunar Valley of Lost Things". In the original, the insects referred to are "cicadas", but, in those days (and later), there was considerable confusion about what this word meant:

De cicale scoppiante imagini hanno
versi ch'in laudi altrui sifanno.

(In the 1532 version, *altrui* is replaced by *dei signor*).

The original is as follows:

La cigalle chantoit, les coulantes riuires
Inuitoient les bergers comme d'humbles prieres
Et de murmure doux, à se baigner dans l'eau:
Les pommes en tombant laissoient leur verd rameau,

.....

Le thym, le pouliot i'ay sauouré le miel
Et toutes les douceurs qui distilent du ciel;
I'ay ouy sur les ormeaux fredonner la Cigale
Mais à ton chant, Bellet, tout cela ne s'esgale.

The old spelling, except for the long "s" is retained. The translation uses "cigale", rather than "cicada" as there is doubt about the insect intended. Since Belleau lived in northern France, he may well have meant the orthopteran *Tettigonia viridissima* Linnaeus in the first verse quoted, but in the second, spelling the word differently and with an initial capital, he may have intended the "classical" Greek *tettix* (strictly a true cicada, but often used for an orthopteran).

Neither Henry Hudson nor Samuel de Champlain fit into our centennial chronology — although there is a body of insect poetry from their times — but I will slip in one quotation from this intervening period as it seems to be the first indigenous North American orthopteran verse and its authoress, Mistress Anne Dudley Bradstreet, died near enough to 300 years ago (in 1672). The poem, *Contemplations,* was published in England in 1650 in a volume called *The Tenth Muse, Lately Sprung up in America.* It includes the following lines:

I heard the merry grasshopper then sing,
The black-clad cricket bear a second part;
They kept one time and plaid on the same string,
Seeming to glory in their little Art.
Shall Creatures abject thus their voices raise,
And in their kind resound their makers praise,
Whilst I as mute can warble forth no higher layes?

The year 1673 marks, not only the establishment, by Louis de Baude, Comte de Palluau et de Frontenac, of the fort at Cataraqui (because of which Kingston now celebrates its 300th Anniversary), but also the epic voyage of Louis Jolliet, Père Jaques Marquette and five companions from Canada down the Wisconsin and Mississippi Rivers to the mouth of the Arkansas. As all of those named were educated men, at least one of them (Frontenac) almost undoubtedly would have read some works by Jean de la Fontaine, including the lately published *La Cigale et la Fourmi* (1668 — one year after the publication of John Milton's *Paradise Lost* which includes magnificent references to locusts). This was based on the old "Aesopian" fable that we know to-day as "The Grasshopper and the Ant". Unfortunately I omitted to bring with me an English version of this, so, before dining, I had to write the following hurried translation, keeping as near as possible to the original.

The green grig who'd indulged in song
All summer long
Found himself to be deprived
Of food when winter's wind arrived.
Not one tiny little mite
Of fly or maggot lay in sight.
Thus did the hungry sycophant
Beg from his neighbour, the ant.

Of her thus asked the mendicant
Some corn to give him nourishment
Till the next season should be.
"I will pay," to her said he,
"In faith as animal, ere fall,
Interest and principal."
But the ant no lender'll be;
Thuswise lacks she the less full well.
"What did you do all that warm spell?"
To this borrower said she. —
"All the time, both day and night,
I sang. You're not displeased perchance?"
"You sang! Why, I am pleased all right!
Very well! Now you may dance."

La Fontaine's version is not a translation from the classics (a common practice of his day). His use of the word *cigale* is in the northern French sense of *Tettigonia viridissima* Linnaeus, a large species of "katydid" or "bush-cricket". This is clear from the vignettes that illustrate his work, and, even if he was not aware of it, from the omnivorous diet ascribed to the insect. *T. viridissima* is known in England as the Great Green grasshopper (or bush-cricket) and English-language tradition (in this and other contexts) translates *cigale* as "grasshopper". The result has been that an acridid is now wrongly implied. Germans, on the other hand, use *Grille* (cricket). The earliest surviving written version of the story is in the Greek verse of Babrios (no later than 2nd Century A.D.), which uses the word *téttix*. This word, to say the least, is ambiguous, although it is identified by Aristoteles with a true cicada. This latter is used in the early Latin version by Avianus (end of 4th Century). *Cicada* and *cigale* are both grammatically feminine, but the above translation, for entomological reasons, makes the singer male! La Fontaine's original is

La cigale, ayent chanté
Toute l'été,
Se trouva fort dépourvue
Quand la bise fut venue:
Pas un seul petit morceau
De mouche ou de vermisseau.
Elle alla crier famine
Chez la fourmi sa voisine,
La priant de lui prêter
Quelque grain pour subsister
Jusqu'à la saison nouvelle.
Je vous paierai, lui dit-elle,
Avant l'août, foi d'animal,
Intérêt et principal.
La fourmi n'est pas prêteuse:
C'est là son moindre défaut.
Que faissiez-vous au temps chaud?
Dit-elle à cette emprunteux. —
Nuit et jour à tout venant
Je chantais, ne vous déplaise. —
Vous chantiez! j'en suis fort aise!
Eh bien! dansez maintenant.

A century after Frontenac had set up his fort near Kingston, the course of history had changed drastically. In 1773, there were troubled times just past and the American Rebellion just ahead. The most notable historic event for Canada

was perhaps the drafting of the Quebec Act, passed in 1774. Indigenous Canadian poetry mentioning insects had still not emerged, so, to represent the period, I will simply quote lines apparently written about this time by Charles Darwin's versatile grandfather, Erasmus, one of the earliest Europeans to advocate biological control of insects. (The lines have also been attributed to the famous physician Edward Jenner, but he presumably merely used them; he was no poet, whereas Darwin was!) The poem was called *Signs of Rain* (Forty reasons for not accepting an invitation to make an excursion). It begins, "The hollow winds begin to blow", and includes:

The Soot falls down, the Spaniels sleep,
And Spiders from their Cobwebs creep [or *peep*]

.....

How restless are the snorting Swine!
The busy Flies disturb the Kine;
Low o'er the Grass the Swallow wings;
The Cricket, too, how sharp he sings!

.....

Through the clear Stream the Fishes rise;
And nimbly catch th' incautious Flies;
The Glow-worms numerous and bright,
Illumed the dewy' Dell last Night;

.....

'Twill surely rain; I see with Sorrow,
Our Jaunt must be put off [or, *cannot take place*] *to-morrow.*

In the interests of bilingualism and biculturalism, perhaps one should also refer to some roughly contemporary French lines from *Le Grillon* ("The Cricket") by the fabulist Jean-Piere Claris de Florian, although they seem to have been written a little later. In English paraphrase they are as follows:

My snug little home is a place of delight:
If you want to live, happy, live hidden from sight!

This "translation" is by Stephen McKenna, 1918. Florian's original runs:

Combien je vais simer ma retraite profonde!
Pour vivre heureux, virons caché!

The first "orthopteroid" verse of which I am aware, for which the poet had any direct connection with Canada falls into the intervening period before the first half-century is reached. Nevertheless, since the Irish author, Thomas Moore, in 1804, wrote his famous *Canadian Boat Song* while staying with Simon Fraser at Ste.-Anne-de-Bellevue, Quebec, very near where I live (the house is still there), I feel almost in duty bound to include a short excerpt from his work. This, I think, appeared about 1817, when controversy over the "corn laws" in Britain was rife. The poem, a political satire, is *The Penwrinkles and the Locusts,* from which comes:

Of all the beasts that ever were born,
Your locust most delights in corn;
And though his body be but small,
To fatten him takes the devil and all.

By 100 years ago, a considerable body of North American insect verse had appeared, with many references to orthopteroids, but almost all was from south of the Canadian border. The nearest thing to a centenarian that I have come across

(and the earliest of which I am aware) in the way of native verse referring to orthopteroids is in a Nova Scotian idyll by Richard Huntingdon entitled "Sunrise on the Tusket", Part 1. It includes the lines:

Still in the light of the morning gray,
That ushered in the summer day,
The fair Acadian hamlet lay

.....

No zephyr's wing the leaf hath stirred,
No sound to break the calm is heard,
Save crickets' chirp or trill of bird.

The end of the 19th Century and the 20th, saw a growth in Canadian poetry, and, with it, appreciable numbers of references to orthopteroids by such poets as Archibald Lampman, W. Bliss Carman, Charles G. D. Roberts, our own Thomas W. Fyles — see *Crickets* in *Ann. Rep. Ent. Soc. Ont. 32* (1901), 1902, p. 90 — Marjorie L. C. Pickthall, Annie C. Dalton, Lloyd Roberts, Louis Dudek and even Paul G. Hiebert (*alias* Sarah Binks), among others.

For 1973, I have chosen to quote from S. W. Grimm's *Tree-Cricket* (in *Trail and Landscape,* Ottawa Field Naturalists' Club, 7 (3), p. 80). As I have no wish to infringe copyright, I give only three lines from the middle of the poem:

With wings turned of lace-glass
cleaning your touch-threads,
Your body pulses with air.

As an unpublished effort for 1973, I give you some lines written for a neighbour whose family had been terrorized by "gigantic" insects — *Ceuthophilus maculatus* (Harris) — in their basement:

The Unhappy Householder

I was a happy householder;
Then camel-crickets found,
With spindly legs and feelers long,
That round my basement bound.

My friend, the entomologist,
Showed no concern at all;
But, damn *you, brown* Ceuthophilus—
You drive me up the wall!

And finally, as we are here looking toward the future, I include the complete volume of *Poems for the Tomorrows* (of uncertain date, as tomorrows never come —which you will agree, is just as well!). This, of course, abounds in profundities of the deepest sociological significance:

grigogram on grass or
ifthatcatcndigitsocnthisbaby

some grigs sing
and some grigs chant;
grig girls grin
as grig guys grunt;
some grigs win,
but most grigs don't;
some grigs are in

and some grigs aren't;
some grigs c'n,
but most grigs can't.
grig-grig-grig-grig-grig-grig-grig-gregarious
grigs are nefarious.
how precarious!
gri-gri grig-grig-grig-grig-grig-grigery-poke-
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it's hilarious!
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the big
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wog?

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